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John Meyer at the top of his 170-foot tower—almost 400 feet above the beach—at his solar and wind-powered home in Washington's San Juan Islands.

Photo by Mike Schmidt

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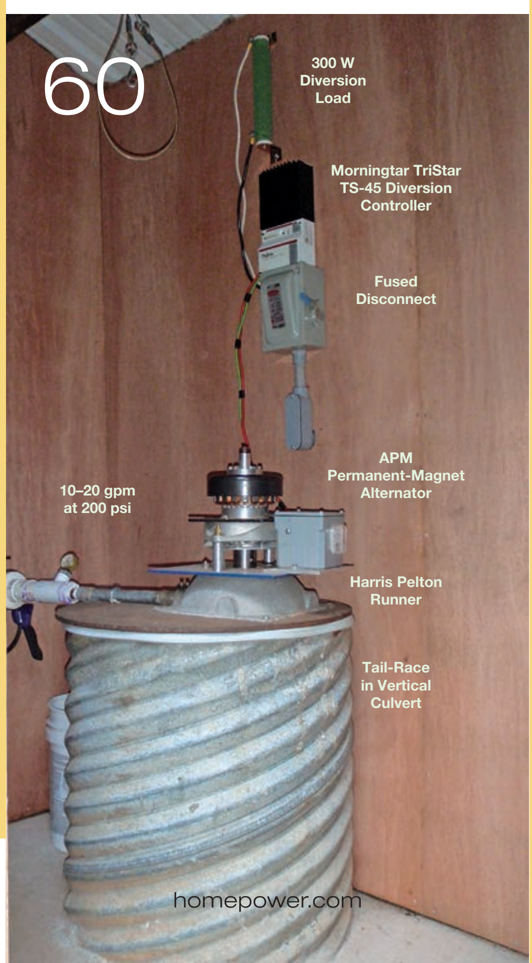

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Photos (clockwise, from opposite page, bottom right): Ian Woofenden; courtesy Toyota; Allan Sindelar; courtesy Advanced Solar Industries; Penny & David Eckert; Khanti Munro.

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The Spice of Life

© istockphoto.com/skodonnell (2)

No matter what your motivation for using renewable energy—the environment, economics, independence, fun, or something else—there's room for variety.

As editors and educators, the *Home Power* staff often gets into discussions with readers, students, and others about "the best" way to deal with specific energy issues, and with the big picture. On occasion, there's more than "discussion," as people can get attached to their own way of doing things.

What's sometimes lost in these discussions is finding common ground and appreciating the variety that humanity brings to bear on any topic. We all have our own assumptions, goals, experiences, and conclusions—and I wouldn't want it any other way. Out of this free thought and variety come new products and endeavors, improved technology, and better examples and practices for the next generations.

Folk singer and storyteller Arlo Guthrie once said of the 1960s, "I came out of that time thinking I'd only met two kinds of people—that's people who give a damn and people who don't. And the truth was that you could find both of those kinds of people on every side of every issue, and in the long run, I thought you might even have more in common with people who care about stuff than you have with people who side with you on an issue or two as they're going through time."

The wisdom there is that caring and trying to do our best is more important than exactly what we do. We can spend forever arguing about what's best, but in the end, *doing* something is probably better than jawing about what others are not doing. It's easy—and fun in an egotistical sort of way—to argue our own point of view and promote our solutions for the world. But what is more likely to *change* the world is each of us choosing to do what we think is best—be it bicycling for transportation, using solar electricity, composting, installing wind generators, or any of hundreds of other things that can improve our personal and global energy picture.

Trying to correct what others are doing or not doing can absorb a lot of our personal and societal energy. And while it's worth speaking truth to power at times, it's a bit too easy to get stuck in our armchairs complaining about others while not doing the good work that's right in front of us—in our homes, businesses, and organizations.

Author Marianne Williamson wisely said that, "…creating the world we want is a much more subtle but more powerful mode of operation than destroying the one we don't want." Let's celebrate the variety of practical and active approaches to our energy and environmental questions, knowing that we're better off with people with conscience and integrity trying different things and learning different lessons than with monolithic "solutions" that may lack creativity and humanity, and can end up being more talk than action.

—Ian Woofenden, for the *Home Power* crew

Think About It...

"Take it easy, but take it."

—Woody Guthrie (1912–1967)

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Home Power Managing Editor **Claire Anderson** lives in a passive solar, (almost) net-zero-energy home she and her husband designed. She and her family are developing their 4.6-acre homestead to incorporate more resilience in their energy, food, and water systems. Chickens were new additions this spring.

Following a career as an instructional designer, in 2010, **Ben Barthell** and a friend started Shopdog, a small construction company in northern New Mexico that specializes in building off-grid tiny houses.

Brad Berman is the editor of PluginCars.com and HybridCars.com. Brad writes about alternative energy cars for *The New York Times,* Reuters, and other publications. He is frequently quoted in national media outlets, such as *USA Today*, National Public Radio, and CNBC. Brad is the transportation editor at *Home Power* magazine.

Roy Butler is the owner of Four Winds Renewable Energy. His home and business have been powered by wind and solar since 1997. He sits on the NABCEP board of directors, and is a NABCEP-certified PV installer and an IREC Certified Small Wind Master Trainer.

In 1977, **Windy Dankoff** started a business in New Mexico to supply wind power to off-grid homes. In 1980, he began to use PV systems for homes and well pumps. Eventually, his company, Dankoff Solar Pumps, became a worldwide supplier. Windy credits his success to taking a whole-system approach to energy efficiency. He retired in 2005 and continues to write, teach, and explore.

Penny & David Eckert live on their 40-acre homestead in Orleans, California, where they enjoy experimenting with the latest in renewable energy technologies, including their grid-tied RE system. Penny still works from home part-time as an environmental permitter, but David is fully retired, which means he never gets a day off from doing chores and projects!

Thirty years ago, **Kathleen Jarschke-Schultze** answered a letter from a man named Bob-O who lived in the Salmon Mountains of California. She fell in love, and has been living off-grid with him ever since. *HP1* started a correspondence that led Kathleen and Bob-O to *Home Power* magazine in its formative years, and their histories have been intertwined ever since.

Christopher LaForge is the CEO of Great Northern Solar and a NABCEP-certified Photovoltaic Installation Professional. He is an IREC Certified Master Trainer in Photovoltaic Technologies. Christopher volunteers with the Midwest Renewable Energy Association and NABCEP. He has a master's degree in philosophy from the University of Wisconsin at Madison and is an organic gardener.

Chuck Marken is a *Home Power* contributing editor, licensed electrician, plumber/gas fitter, and HVAC contractor who has been installing, repairing, and servicing SWH and pool systems since 1979. He has taught SWH classes and workshops throughout the United States for Sandia National Laboratories, Solar Energy International, and for many other schools and nonprofit organizations.

Khanti Munro is the director of development and technical design at Same Sun of Vermont. He is a NABCEP-certified PV installation professional and a PV instructor for Solar Energy International. Munro holds a degree in Renewable Energy Applications from Green Mountain College, and was formerly a technical trainer for SunEdison.

Justine Sanchez is *Home Power*'s principal technical editor. She's held NABCEP PV installer certification and is certified by ISPQ as an Affiliated Master Trainer in Photovoltaics. An instructor with Solar Energy International since 1998, Justine leads PV Design courses and develops and updates curriculum. She previously worked with the National Renewable Energy Laboratory (NREL) in the Solar Radiation Resource Assessment Division. After leaving NREL, Justine installed PV systems with EV Solar Products in Chino Valley, Arizona.

Andrew Savage is Chief Strategy Officer at AllEarth Renewables. He also serves on the Board of Directors of the Solar Energy Industries Association (SEIA) as vice chair of the Distributed Generation Division.

Allan Sindelar installed his first off-grid PV system in 1988. He retired from Positive Energy Solar of Santa Fe, New Mexico, in 2014, and now designs, services, and consults on off-grid and water pumping systems. He is a licensed electrician with dual NABCEP certifications.

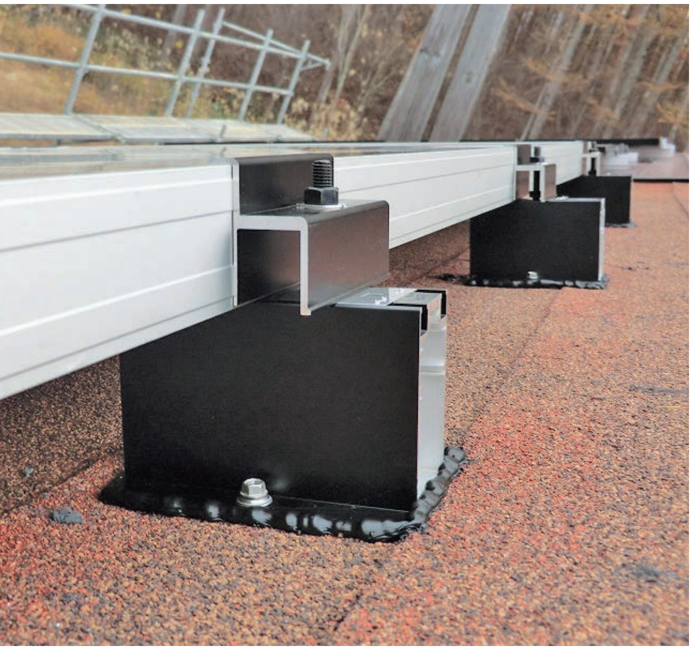
Alex Wilson is the founder of BuildingGreen, the Brattleboro, Vermont-based publisher of *Environmental Building News*, *GreenSpec*, and LEEDuser.com. He is also president of the Resilient Design Institute.

Vaughan Woodruff owns Insource Renewables, a solar contracting firm in Maine. Vaughan has developed curricula for and is currently teaching two online courses—Solar Approaches to Radiant Heating (through HeatSpring) and Solar Heating Design & Installation (through Solar Energy International).

Home Power senior editor **Ian Woofenden** has lived off-grid in Washington's San Juan Islands for more than 30 years, and enjoys messing with solar, wind, wood, and people power technologies. In addition to his work with the magazine, he spreads RE knowledge via workshops in Costa Rica, lecturing, teaching, and consulting with homeowners.

Contact Our Contributors

Home Power works with a wide array of subject-matter experts and contributors. To get a message to one of them, locate their profile page in our Experts Directory at **homepower.com/experts**, then click on the Contact link.



Courtesy Roof Tech

Roof Tech

RT-[E] Mounts

Roof Tech (roof-tech.us) released its RT-[E] Mount line of rail-free mounting brackets for composite shingle roofs. These products can be fastened to roof rafters or to the decking. Once PV modules are secured to the brackets, the array is electrically bonded. The Roof Tech products utilize butyl rubber spacers and caulk for water-seal, and can be used with standard module thicknesses. Cable management and bonding plates (for grounding) are included in the clamp kit. The RT-[E] Mount AIR provides 3 inches between the roof and the array (compared to 1.2 inches for the regular mount) for use with microinverters or good airflow in hot climates. Microinverter brackets and an array skirt (for aesthetics) are options for the RT-[E]Mount AIR. These mounts have a 10-year warranty.

—Justine Sanchez

Courtesy Trojan Battery

Trojan Battery

Reliant AGM Batteries

Trojan Battery Company (trojanbattery.com) launched its Reliant line of deep-cycle AGM batteries. Manufactured in Sandersville, Georgia, these sealed, maintenance-free batteries are offered in three 6 V models: the T105-AGM, J305-AGM, and L16-AGM. The capacities (20-hour rate) are 217, 310; and 370 Ah, respectively. Additionally, there are 8 V and two 12 V versions available, with 20-hour capacities of 160, 150, and 200 Ah, respectively. This line features Trojan's C-Max technology—thick plate separators that help protect against stratification—and one flame arrestor per cell to increase safety.

—Justine Sanchez

MIDNITE SOLAR

Rapid Shutdown System (NEC 690.12)

The Birdhouse is now UL 1741 listed

The MidNite Solar Rapid Shutdown System is a firefighter and homeowner's safety control system. This system has been designed to disconnect and isolate power from the PV panels, batteries, inverters and generators on any PV configuration.

In case of an emergency, or for routine maintenance, pushing the large red button of the Birdhouse sends a signal to all disconnecting modules and then returns feedback that they actually are disconnected. MidNite's Rapid Shutdown system is the only system that provides visual and audible confirmation that power has been disconnected.

The Birdhouse's LEDs display the system status based on hard wired feedback and automated speech gives further situation specific information.

The Birdhouse is available in red or gray!

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Streamlined Supply-Side Interconnection

Unique challenges to this batteryless grid-tied system required creative planning and using an innovative product.

Supply-side connections interconnect a PV system to the grid without being hindered by common load-side limitations, such as mains panel busbar size and whether there's space for another circuit breaker. Supply-side connections are often more complex than load-side connections, and may still require accessing the main distribution panel (MDP) to splice into the incoming service conductors. However, this new interconnection method only requires meter access, and does not require working within the MDP.

The Akin family was determined to meet some of their electrical needs with renewable solar energy, but needed to develop the system as their finances allowed. Complicating matters were a completely shaded rooftop, which meant locating the array on a ground- or pole-mount. They decided that implementing the array in two stages, as two ballasted ground-mount subarrays, was a workable solution.

To avoid trenching more than once across the lawn, additional conduit was installed in the trench and run to the site of the second subarray. An AC inverter/combiner panel that can accommodate two inverters was placed adjacent to the first inverter, which was mounted to the first array. The AC output conductors running to the house were sized to meet the eventual combined output of the two inverters.

Khanti Munro (2)

The ConnectDER is mounted between the service kWh meter and the meter base for a simple supply-side connection.

Interconnection was also complicated by the MDP, which was fully recessed into one of the dining room walls. Although a load-side interconnection (backfeeding a dedicated circuit breaker in the MDP) was possible because of a projected maximum inverter output current of 30 amps (15 A × 2) and a 200 A MDP, it was not practical or cost-effective. There were also no existing subpanels in the house. Interconnecting at the MDP would have been more costly, since it would have required cutting (and then repairing) the wall.

continued on page 18

Overview

Project name: Akin residence

System type: Batteryless grid-tied

Installer: Same Sun of Vermont

Date commissioned: November 2014

Location: West Rutland, Vermont

Latitude: 43.59°N

Average daily peak sun-hours: 4.21

System capacity: 3.3 kW STC

Average annual production: 3,720 AC kWh (estimate accounts for some minor shading)

Average annual utility bill offset: 50%–60%

Equipment Specifications

Modules: 12 SolarWorld SW 275, 275 W STC

Inverter: SMA America Sunny Boy 3000TL-US; 3 kW rated output

Array installation: Ground mount; 180° azimuth; 30° tilt


Khanti Munro

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An innovative "collar" device—the ConnectDER—provided a streamlined method for code-compliant supply-side interconnection (*NEC* 705.12A). The ConnectDER is installed in-line between the utility meter and the meter socket, with the inverter output circuit terminating at the collar's wire-box. An integrated two-pole breaker provides both overcurrent protection and a disconnecting means, negating the need for a separate fused PV system disconnect enclosure. The integrated disconnect is accessed via a removable gasketed cover on the top or bottom of the collar, depending on the version. The local utility not only approved the use of the device, but also assisted with its distribution. The method avoided the need to penetrate the building, saving both labor and material costs, and avoided disturbing a busy family.

—Khanti Munro, with Phil Parrish

Solar Trackers: Big Output from a Smaller Footprint

Courtesy Advanced Solar Industries

Maryland homeowner Tom Lomax was looking for a solar solution that would not take up too much room, but would meet his household's annual energy consumption. A rooftop installation was ruled out—the south side of his home's roof had dormers, making it difficult to avoid significant loss of power from shading. That narrowed the choice to a pole- or ground-mounted system.

Although he had other estimates for ground-mounted systems, it was Pennsylvania-based Advanced Solar Industries' (ASI) proposal—two arrays on dual-axis trackers—that caught his attention. Not only would the arrays fit in a smaller area than a ground-mounted array, but they would produce more energy, bringing his home to net-zero energy use.

The entire AllEarth Renewables tracker assembly was pre-engineered and arrived on a single pallet. The Series 24 AllEarth Solar Tracker is a dual-axis active tracker that uses a hydraulic system to keep the modules perpendicular to the sun's rays. The tracker, powered by a 208 or 240 VAC electric supply, uses less than 1% (between 50 and 90 kWh) of the array's annual production. At this site, compared to a fixed array of the same size, the installer estimates an increased production of about 1,600 kWh per kW (more than 30%).

The concrete bases for the trackers were precast and, after the ASI crew dug holes for each tracker, lowered in with a forklift. The mast was anchored to the base with four 1-inch, threaded rods and nuts, and direct-tension indicator washers. The tracker racks were assembled on site.

Each tracker is equipped with GPS and wireless technology to accurately position the arrays with the sun, and send and receive data. Anemometers atop each tracker measure wind speed and activate the tracker's automatic stow function during high winds.

Tom uses a wireless router cellphone hotspot with a Sunny Web Box to send tracker and inverter production data to the SMA America Sunny Web portal. Sunny Boy inverters were used because Tom may eventually incorporate battery backup using SMA Sunny Island inverters to provide electricity during grid outages.

"I moved into my new home on the family farm in 2009, and for five years dreamed of having solar," says Tom. "My motivation was driven by both environmental awareness and the desire to invest in a system that would counter the ever-increasing costs of energy."

—Andrew Savage

Overview

Project name: Lomax residence

System type: Batteryless grid-tied

Installer: Advanced Solar Industries

Date commissioned: October 3, 2014

Location: Bel Air, Maryland

Latitude: 39.6°N

Solar resource: 4.7 daily peak sun-hours

System capacity: 12.24 kW STC

Average annual production: 19,600 AC kWh

Average annual utility bill offset: 100%

Equipment Specifications

PV modules: 48 Conergy PE255P, 255 W STC each

Inverters: Two SMA America SB6000 US, 6 kW each

Array installation: Two AllEarth Solar Trackers

Comment & Discuss this article @ homepower.com/167.20

Solar Bus

Blue skies, not a cloud in sight. A great day for driving a typical 1966 VW Bus; a perfect day for an electric bus with 10 solar-electric modules affixed to the roof. I bought the bus to convert it to electric, and took it a step further—with solar. The bus might look a little funny, but it's proving that solar-powered vehicles can be practical.

The conversion process was a lot simpler than I expected and took only a few days. The first thing I did was connect a potentiometer to the throttle. Then I removed the engine and replaced it with an electric motor. After that, I connected a motor controller and the batteries. It was then ready to drive!

The components used are:

- Elmo motor controller
- Moog brushless motor
- Solbian solar-electric modules (10, 130-watt modules on the bus; 20, 100-watt modules on trailer)
- Genasun solar controllers
- Manzanita Micro battery charger
- Boston Power's Swing 5300 lithium-ion batteries

This vehicle is great for city driving. Slower, flatter routes are best. Driving this vehicle has made me think about the routes I take when driving a normal vehicle. There's a big hill on the shortest route to my kids' school, and I watch the battery drain as I accelerate up the hill. Taking a slightly longer, but much flatter route uses just a quarter of the energy. Avoiding hills and opting for routes at slower speeds yields optimal results. Routes with more sun and less tree overhang also increase the range.

The bus can go 74 miles per hour, but again, going that fast wastes a significant amount of energy due to wind resistance. It has a range of about 35 miles if there's no sun, based on energy stored in its batteries. Range could be increased by simply adding more batteries, but would also add weight and cost.

The bus gets a lot of attention. When I first bought it, my kids would not go near it. They were so embarrassed, but their friends thought it was so cool. I also often get notes left on the windshield when it's parked somewhere, sometimes because it's an old VW bus, other times because it's solar-powered. People have actually stopped in traffic to wave or ask me about it.

Daniel Theobald • Cambridge, Massachusetts

Courtesy Daniel Theobald

Daniel Theobald's PV-powered 1966 VW Bus.

Walls & Moisture Debate

I was surprised that David Posluszny, the owner/builder of the home profiled in "Solutions" (*HP162*), chose to put a vapor barrier on the cold side (outside) of his home's walls. More commonly here in the North, the vapor barrier is put on the "warm" side, with the goal of preventing water vapor from entering the walls (as opposed to preventing it from escaping).

There are at least three mechanisms for transporting water or water vapor into or within a wall. The author is right that movement of air is one method. Diffusion is another, and so is wicking/draining. All of the published specifications for permeability are based on zero air movement. The reader is advised to read up on "wet cup permeability."

Unfortunately, stopping air movement doesn't stop moisture movement into a wall. Air movement into a wall and back out again from the outside is called "wind washing," though homeowners might benefit by calling it "wind drying." Wind drying removes the small amounts of water vapor that pass through or around a well-detailed vapor barrier like 6-mil polyethylene. As long as the walls are not too tightly sealed on the outside, this moisture escapes to the atmosphere with no harm.

The homeowner in the article stymied wind drying with his choice of a cold-side vapor barrier. There isn't a lot of wind drying that goes on through OSB or CDX plywood. The relevant term here is "air permeance," and though it's minimal through wood products, it's much higher than through rubber sheeting like Grace Water & Ice. It doesn't take a lot of air movement to dilute and remove the moist air that accumulates within a wall when it's very cold outside.

Accumulated water inside a wall rots wood, and causes mildew and other fungi to grow. The cheaper brands of cellulose insulation are treated with ammonium sulfate, which produces an ammonia smell when wet. Wood rot starts at 97% relative humidity and fungal growth starts at 75%. It's unwise to reduce energy bills at the expense of having an uninhabitable structure due to indoor air-quality issues and structural failure due to rot.

Pete Gruendeman • La Crosse, Wisconsin

Your points would be well justified if you're talking about using a hydrophobic insulation product, such as fiberglass and foam. However, I insulated my home with dense-pack cellulose insulation. With this insulation, my system works beautifully and there is no wetting or rotting. I have been testing my exterior sheathing for moisture, as well as several homes with "well-detailed vapor barriers" on the inside. My wall and roof

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Courtesy David Posluszny

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assembly are dramatically drier than every fiberglass and foam-insulated house I have tested.

You accurately shared the definition of the term "wind washing," and then offered another title of "wind drying." Here are a few more that could be used: "heat loss," "water intrusion," and "zero control." It's not good when a home is built with a focus on what happens for one part of the year, at the sacrifice of the rest of the year. Wind blowing into a stud cavity might have drying potential during some conditions, but under other conditions the same leaks will cause water buildup, and it will always cause energy loss. We should build homes that work in all conditions. The most common source of water damage to a home is from outside water coming in. That should be addressed and controlled first.

David Posluszny • Dolphin Insulation

There is always more than one way to solve a problem, and each solution will have its advantages and disadvantages. I like the elegant simplicity of Dave Posluszny's system, but I am concerned about trapping moisture. I think it would be a lot better to wrap the house in a highly vapor-permeable, yet waterproof, barrier, such as ProClima's Solitex Mento 1000. This weather-resistive barrier (WRB) is like Tyvek, but with better performance. I would also add a rain-screen detail (exterior strapping) between the WRB and the siding.

Alex Wilson •
Home Power *building science editor*

Water Success

I enjoyed the discussion of water pressure in "Mailbox" (*HP164*). Malcolm Drake likes using gravity-fed water at lower pressure, while Windy Dankoff urges using a pressure tank to eliminate bacterial growth and the need for very heavy storage tanks.

I have used both systems. Dankoff helped me set up my first water system in the 1980s. (He also sent me *HP1*, and I have subscribed ever since). I had no well, but used a small, solar-powered 12 V Slowpump to push water from my lake uphill to a 50-gallon tank, 15 feet "above" the sink and shower. I sometimes added a few drops of bleach to the tank. There was barely adequate pressure through the 12 V ultraviolet purifier for drinking water.

When my dome was built in 1992, I had a well drilled. I bought a plastic-bodied, 12 V submersible Flowlight Quad pump that supposedly had an average life of seven years. Figuring I could extend its life by reducing the times it had to start up, I bought a very large pressure tank. The pump lasted 19 years.

I now use a model SDS-D128 Sunpump made of stainless steel and brass. It draws only 1.5 amps and is slow (it was meant for 24 V systems). The pump, which activates at 20 psi and shuts off at 40 psi, is adequate for all my water-pumping needs.

Thanks for the great work you've done to help us over the years—and keep those do-it-yourself articles coming, too. My self-installed PV system has worked flawlessly since 1984.

Larry Behnke • High Springs, Florida

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Black Frames?

I have noticed a propensity to sell black components. I suppose black frames and rails offer less contrast with PV cells, which are usually black or dark blue. This preference for black has a downside: The darker surfaces facing the sun absorb more heat. This added heat reduces a PV array's voltage, resulting in less power and less energy produced. How much of a drop in power depends on several factors, including the roof color and surface material, and airflow.

The penalty in lost power and energy production is not insignificant. Compare the PTC ratings between the clear-framed and black-framed version of otherwise identical PV modules and the difference can be in the 1% to 5% range.

Solar thermal collectors are black so they can absorb more heat. However, black PV modules and frames are just a cosmetic preference. It costs more and produces less. So why the preference? When I see a light-framed PV array on a light-colored roof, I see something that's energy efficient and durable. To me, that's beautiful!

Marc Fontana • via email

Courtesy SunPower (2)

Community

Thanks to Sarah Lozanova for the great article on the Belfast Cohousing & Ecovillage community in *HP165*—I wish you all success! I'm starting to think about starting an ecovillage in Colorado, and was wondering how you managed to get together people who would be compatible, and also, how you manage to resolve the inevitable conflicts/disagreements that arise in a community?

David Congour • via homepower.com

That's a great question, David. We joined BC&E during the development phase, but after a core group was established. The community resonated with us because the mission is in line with our values. We visited or met with several communities, both established and forming, and this one seemed to be the best fit for us. I was more interested in joining an established community because it can often take five years or more to form an intentional community.

Conflict is inevitable, but I think what is more important is if it can be worked through productively. BC&E is experimenting with the use of dynamic governance, with distributed leadership. This is helping to reduce the time spent in general meetings, while striving to create more productive meetings.

Before joining BC&E, I read a couple of books on intentional communities. I recommend: Creating a Life Together: Practical Tools to Grow Ecovillages and Intentional Communities *by Diana Leafe Christian and Patch Adams; and* Finding Community: How to Join an Ecovillage or Intentional Community *by Diana Leafe Christian.*

Visiting communities is a great way to get started. The Fellowship for Intentional Communities website (ic.org) has a directory of forming and existing communities. You can also advertise that you are forming a community to help attract potential members. All the best in your endeavor!

Sarah Lozanova • Belfast, Maine

Mystery Module

I have a really old solar module and have been trying to identify it. There is no manufacturer label on it. It has approximately 2.5-inch, circular blue monocrystalline cells with radial-oriented traces imposed upon them. It has a textured glass front and aluminum backing, and appears to be commercially manufactured as opposed to homemade. I have never seen another module even similar. It's been difficult to determine if this module was produced before or after Arco's round monocrystalline-cell module. It looks older, but the radial trace pattern on the cells seems more sophisticated. I wonder if any *Home Power* readers will recognize it.

Courtesy Mike McCormick

Help identify this still-functional vintage PV module.

The module still works! I buy and sell used solar equipment, and like to show my customers how this technology can continue working for 40-plus years.

Thanks so much for making your entire archive available with this year's subscription. It is literally the history of solar and other RE technology. This is the single best, most valuable offering I have ever seen—period.

Mike McCormick • via email

write to:

mailbox@homepower.com

or Mailbox, c/o Home Power
PO Box 520, Ashland, OR 97520

Published letters are edited for content and length. Due to mail volume, we regret that unpublished letters may not receive a reply.

Landscape PV Module Mounting

I've seen many photographs that show rooftop PV modules mounted in a landscape orientation. As an experienced installer, I know that rails most often need to be run perpendicular to the narrow width of each module and within a specified distance from either end of the length of the modules.

However, many modules are not rated for the rails running parallel with the landscape orientation. So to mount in landscape, the rails need to run parallel to the trusses. But trusses are often on 2-foot centers. If you do the layout, you cannot have the attachment point hit the truss and meet the requirements for the rails under the modules. After a column or two, you either miss the truss or you are not landing the module on the rail per the manufacturers' specs.

So what are these installers doing? Are they getting up in the attic and installing cleats across the trusses? Is there a standoff that is engineered to go into the sheathing? Or are they disregarding the manufacturers' specifications?

Kirk Haffner • Olympia, Washington

An article in *Home Power's* sibling magazine for professionals, *SolarPro*, discusses this issue. While landscape orientation can allow a greater number of modules on certain roofs, potential stresses on either the module frame or the building structure is a concern.

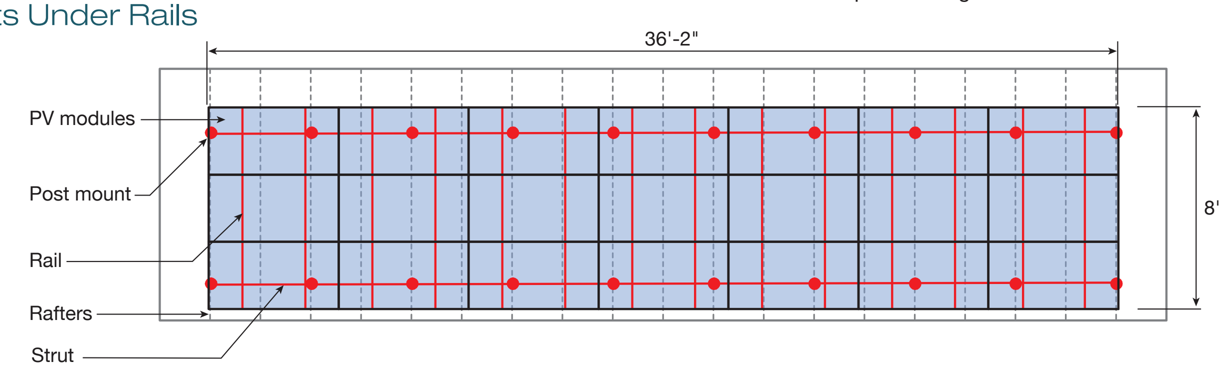
Generally, you can use one of four approaches:

- Add a "strut sublayer" to the rail system that's perpendicular to the rafters
- Add cleats to the rafters to get the proper rail spacing. This can be challenging and labor-intensive, but will meet the equipment's structural requirements.
- Use specialized anchors that allow fastening into the sheathing rather than into the rafters. Some products allow anchoring directly to sheathing as long as it is of adequate thickness.
- Use modules that specify clamping on the module's short side. For example, Sanyo HIT modules specifically allowed use of the short side of the module frame for clamping.

Improvements in module manufacturers' installation manuals have led to clarity in several areas of installation. However, installers must adhere to the manufacturers' requirements in order to maintain warranties and UL listings.

Christopher LaForge • Great Northern Solar

Mounting Modules in Landscape Orientation Using Struts Under Rails



Upgrading DC Pumps

II have a 3 kW solar-electric array near Cape Town, South Africa. It is an off-grid, 24-volt system. When the batteries need to be replaced, we will upgrade to a 48-volt system—but the batteries are in good condition, so we're delaying the upgrade. Our problem is this: Among our normal household loads, we run two AC water pumps—one for the garden and one to supply the house. Each pulls about 1.1 kW, and when the pumps and a few other loads run simultaneously, our 2 kW inverter trips.

Is there a 24/48-volt DC water pump (preferably brushless) to supply the house, that can deliver around 10 gallons per minute at 40 to 60 psi?

Waldo van Essen • Cape Town, South Africa

To accommodate your future upgrade, I can suggest three general options:

- Use the existing AC pumps but implement some load-management strategies to avoid tripping your inverter. For example, you could automate your loads so that when one pump is running, a simple relay will disconnect a competing load.
- Replace one or both of your AC pumps with soft-start electronic-motor pumps, like the Grundfos MQ series. These pumps are *not* more efficient than traditional (induction motor) pumps, but they have a lower startup surge. It's this surge that trips your inverter. If you have abundant energy and can afford some waste, then these AC pumps may be most economical.
- If pumping is a major system load, you may benefit from upgrading to high-efficiency (but more expensive) DC pumps, since they will use less than half the energy—then switch to a higher-voltage motor when you upgrade your system.

Unfortunately, there are no dual-voltage DC pumps that provide equal performance at both 24 V and 48 V. If you get a 48 V pump, you can run it at 24 V, but it will run at half-speed. If the pump is a centrifugal type, this won't work, because it will produce only 25% of the pressure. If the pump is a positive-displacement type, it will work fine at full pressure—but at half-flow. You can find piston and helical rotor pumps to satisfy your flow requirements at 48 V, but until you upgrade your system, you will be stuck with half the rated flow.

You might consider buying a 24 V pump and replacing only the motor when you upgrade to a 48 V system. While a classic brush-type DC motor is fine, a brushless motor is slightly more efficient, and it may be an option if the motor's controller (part of the brushless system) is dual-voltage. Then, only the motor itself needs to be changed. You'll need to shop around, then ask about the feasibility and cost of motor replacement.

Windy Dankoff • Founder, retired, Dankoff Solar Pumps

Radiant Foil

We bought our home two years ago, moving from a much milder part of the San Francisco Bay Area to Novato, California, where the temperature swings are considerably greater. We have spent large amounts of time, energy, and money on improving the efficiency and comfort of our home by insulating floors and walls; installing high-efficiency windows and doors; and planting trees along the southwest side to shade the house. We also installed a grid-tied solar-electric system.

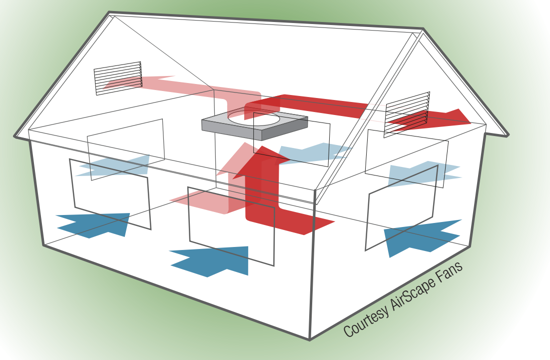
All of this has dramatically improved the comfort of our home. However, Novato is very warm in the summer, and I refuse to install an air conditioner. Our next steps are to replace the soffit vents with larger vents and install a whole-house fan to more quickly cool the structure when the outside temperature drops in the evening.

The question I have concerns the efficacy of affixing radiant foil to the underside of the roof rafters. Would this be an effective approach to keeping the house cooler during hot summer days?

Paul Ashwood • Novato, California

Radiant foil can significantly reduce summer household heat if—and this is a big if—your attic is very poorly insulated. If your attic floor is well-insulated, the radiant barrier at the rafters will help keep the attic space cooler, but there will be little difference in how much unwanted heat is transferred into the living area. Radiant barriers are often greatly oversold, so be careful about marketing claims and advertising.

You said you were against air conditioning, but have you considered a minisplit system instead? If your existing space-conditioning equipment is due for replacement, consider installing an electric minisplit air-source heat pump. This solution offers several advantages:



A whole-house fan drawing in cool nighttime air can keep a closed-up, well-insulated house cool all day.

- Because of the heat pump technology, the cost per unit of delivered heat is relatively low. It is usually significantly less expensive than propane or heating oil, and sometimes competitive with natural gas. See "Heat Pump Primer" in *HP149* for more on this heating and cooling strategy.
- Heat pumps also provide cooling—though, like you, I prefer cooling a house with natural ventilation. Install a whole-house fan and open the house up at night to cool it; then close it up during the day to minimize unwanted heat gain.
- If your PV system generates a surplus of electricity, you might even be able to offset any mechanical cooling with renewably produced energy.

Alex Wilson • *Home Power* building technology editor

Battery Box Coating

I just finished reading Allan Sindelar's "Battery Box Design" article in *HP141* (homepower.com/141.96). He suggests that a simple battery box can be built from plywood, but recommends lining the interior and also using a penetrating oil or paint to help the wood resist minor spills. I'm wondering if he has any specific brand recommendations for coating the plywood?

Luis Pérez • via email

I don't have particular coating brands to suggest, as it's not that critical. You just need a barrier between any spilled, splattered, or leaked sulfuric acid electrolyte and the plywood, which will rapidly deteriorate on contact with the acid. I have used clear polyurethane and latex-primer finishes, in both oil- and water-based forms. The water-based formulas generally have fewer volatile organic compounds (VOCs) and are easier to clean up (both from your skin and brushes). All work well for the inside of the box, as the EPDM or PVC pond-liner material serves as the heavy-duty barrier. On the exterior, your choice has more to do with aesthetics: a clear finish on higher-grade plywood can turn the box into attractive cabinetry.

Allan Sindelar • SindelarSolar.com

This well-sealed and vented battery box contains an EPDM liner and painted interior.

Allan Sindelar (2)

SHW Plumbing Insulation

We had a solar domestic water heating system installed in 2004. All has worked well thus far. However, the plastic pipe insulation shield on the exterior pipe run is starting to disintegrate. Do we need to repair this immediately, or can it wait until warmer weather arrives?

The system is two 4- by 10-foot solar collectors manufactured by AET. The 140 feet of 3/4-inch, type M copper tube is covered by 1-inch-thick pipe insulation—isocyanurate on the exterior pipe and wrapped fiberglass on the interior pipe.

Marlow Shami • via email

Pipe insulation serves a heat loss function in solar water heating systems, and should be routinely inspected for deterioration. In your case, it is possible that the insulation covering—which should be a rigid plastic sleeve—has started to disintegrate, jeopardizing the durability of the insulation underneath. An immediate repair isn't critical—you can wait until warmer weather comes.

The covering over the isocyanurate insulation may be Snow Roof or a product like it. It's used on many mobile home roofs, and will usually last about 10 years on exterior pipe. We usually use foil tape, available at most hardware stores, to wrap pipe insulation. It is a two-part tape—foil with a backer that you peel as you apply the tape. It usually lasts 10 or 20 years.

If you want something that will be even longer-lasting, use lightweight architectural grade aluminum, which bends easily, but is thicker than a soda can. Pipe insulation without any weatherproofing usually disintegrates within a few years.

Chuck Marken • *Home Power* thermal editor

Chuck Marken

Routinely inspect your pipe insulation covering and the insulation beneath to keep potential freezing problems at bay.

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Taking a Tiny House OFF-GRID

Allan Sindelar

by Allan Sindelar, with Ben Barthell

A battery-based solar-electric system can be the perfect match for a "tiny house," cabin, or other small home. This guide will help you determine what loads to serve, explain equipment selection and sizing, and present installation and maintenance tips for a small, robust off-grid PV system. We will examine a case study for a real-world tiny house—Ben Barthell's off-grid, 200-square-foot Steely Cottage in Espanola, New Mexico.

Basic Principles

Off-grid living requires adherence to three basic principles of energy use as the basis for a power system:

- Shift inappropriate electrical loads (space and water heating, cooking, and clothes drying) to other forms of energy
- Reduce waste by implementing efficiency measures
- Use energy in proportion to the amount available.

In an off-grid home, the energy system alone serves the daily household electricity needs, and batteries can store only a few days' worth of energy. Energy use is typically greatest in winter, when more hours of darkness mean more indoor activities and lighting—and comes at the season with the least solar resource, due to short days and more clouds. An off-grid PV system is usually sized to meet winter demand, which means it is oversized for needs during the rest of the year. In a sunny climate, a well-designed off-grid PV system will typically meet 80% to 90% of the home's winter load, usually with an engine generator making up the rest.

web extras

For an explanation of these three principles, see "Toast, Pancakes and Waffles" • **homepower.com/133.88**

THE STEELY COTTAGE

Twenty years ago, well before tiny houses became popular, Ben Barthell dreamed of building a self-contained, PV-powered home. His charter was simple: Include everything he needed and nothing else, with the functional amenities of a "normal-sized" house—just smaller.

In 2010, Ben sold his 3,000-square-foot home in Minnesota and everything he no longer needed. He settled on northern New Mexico land belonging to a longtime friend, and purchased a used flatbed trailer, pickup truck, and materials to start his "tiny home" project.

His so-called "Steely Cottage" was built from scratch on a 24-by-8.5-foot flatbed trailer. Construction took a year to complete. The exterior is clad in recycled COR-TEN steel sheets, which have weathered to a rusty patina, allowing the exterior to be maintenance-free for life. The roof is covered with an EDPM rubber membrane that is rated for 60 years.

The house was constructed using 2-by-6 and 2-by-4 wood framing. There's R-9 fiberglass batts in the 2-by-4 walls, R-19 batts in the 2-by-6 ceiling, and R-20 rigid foam in the floor. Standard construction techniques were used throughout with plywood sheathing, Tyvek house wrap, moisture barrier on all surface/floor/ceiling/walls, and a wallboard interior finish. All of the windows are double-pane vinyl. Doors are insulated wood with double-pane lights. The house weight was considered in all construction materials, since, to be transportable, its "gross vehicle weight" could not exceed 14,000 pounds. The completed house (weighed at a weigh station) tips the scales at 10,500 pounds.

Ben Barthell (3)

The kitchen has an Amana 20-inch LPG stove, 24 V SunDanzer fridge/freezer, lots of storage, a double sink, and counter room to prepare meals. The bedroom has a queen bed with drawers underneath and closets at both ends. The living area has a drop-down laptop desk and sofa/table unit. The house is heated by a wood heater, with some passive solar gain through the south-facing door.

Plumbing is conventional PEX plastic pipe. An onboard pressurized water system consists of a 70-gallon storage tank that pump-feeds a 40-gallon pressure tank, and pressurizes the water at 50 psi. Water is added to the onboard tank once a week or so. The bathroom has a shower, vanity, and Separett 9200 Villa composting toilet, with a 110 V vent fan. Greywater and compost feed on-site gardens. Water is heated by a closed-loop 4-by-8-foot solar collector with a heat exchanger that sits inside a propane-assisted 15-gallon water heater tank. Water is circulated via a 120-volt pump powered by the PV system. The water heater's burner seldom fires, given the abundant New Mexico sun.

This little home has plenty of comforts and amenities, with no electricity bills, mortgage, or big-house maintenance expenses. Although known as "tiny houses" in the United States, Ben points out, in much of the world, 200 square feet would be considered normal. He prefers to call his home a "world" house, since he believes that a small family could thrive in one, and use the savings of time and money to live a fuller life. The cost of materials, components, appliances, and the electrical and water systems was $32,000—not including labor. Ben built and designed this home himself. A basic rule in construction is value labor expenses equivalent to materials' costs. Factoring that in, a similar turnkey tiny house might cost between $50,000 and $60,000. Ben's company, Shopdog (shopdog.biz), customizes off-grid tiny homes that, he says, have all the amenities of a typical home.

"This charter seems simple, but can be difficult to achieve," he says, "since we want these homes to be lived in, day in and day out—year 'round—and not just be a cabin used a few weeks during the year."


Allan Sindelar

Ben Barthell's dream of a tiny home always included a PV system for independence from utility electricity. But as he researched solar components, he was overwhelmed by the many products available. He decided to consult with me and the installation company I founded, Positive Energy Solar.

He wanted the electrical system to meet the majority of his needs with minimal dependence upon a backup generator—and a system that would be capable of maintenance-free unattended operation for months at a time. Ben requested a preassembled and fully programmed PV system that he could take home to install himself, with diagrams and telephone support as needed. After several discussions, I designed a 750-watt battery-based PV system for his tiny house.

DIY or Pro?

If you plan to install your own system, you will be wise to partner with a seasoned off-grid professional who can help you clarify what you're seeking. A pro often hears more "between the lines" than you verbalize, such as whether you'll be willingly engaged with your system's ongoing maintenance or are better served by a system designed to need minimal care, and often knows the questions you don't yet know to ask. A contractor with experience designing and installing off-grid systems can save you more, in both dollars and headaches, than they will cost.

Your system's components must be properly programmed for best performance and battery life. For a fee, some will assist you in sizing and designing your system, then preassemble and program the balance of system (BOS) components, leaving it for you to install. Some may even review your installation before it's commissioned.

However, you may not have an experienced off-grid designer/installer available in your area, since batteryless grid-tied installations are dominating the market. If you have no such resource where you live, consider an Internet-based company that specializes in off-grid systems.

If you decide on a pro installation, plan to purchase equipment through them. Working with an installer usually includes follow-up guidance and assistance when questions or problems arise. You're building a long-term relationship, and someday when the lights suddenly go out, you'll be glad you did.

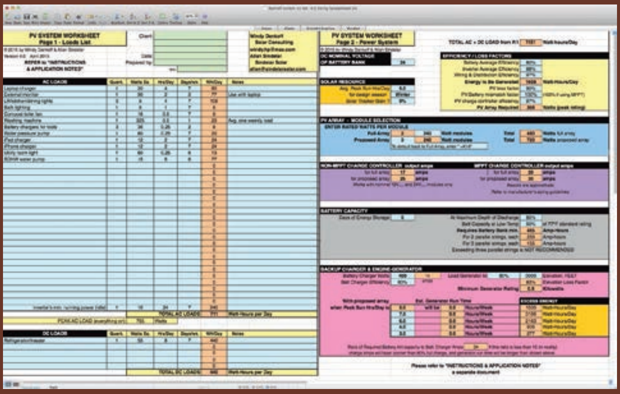
Estimate Your Loads

A load analysis measures or calculates the electricity consumed by each device in your home, and estimates the average daily energy consumed by all loads. By quantifying each load, the PV system can be sized to meet the home's needs. An analysis also helps identify overlooked or inappropriate loads, potential problems, and ways to use less energy to achieve the desired result, which can reduce PV system size and cost.

Most important, it serves as a valuable education process. Most who live with utility power have little reason to know how much electricity is used and for what purposes. Preparing a load analysis is an effective consciousness-raising activity. By understanding how and where you're using electricity, you'll be more likely to be satisfied with the limits and blessings of your PV system.

BARTHELL SYSTEM LOADS

AC Loads	Qty.	×	Watts Each	=	Total Watts	×	Hrs. / Day	×	Days / Wk.	÷ 7 =	Avg. Daily Wh
Laptop charger	1		20		20		4.00		7		80.00
External monitor	1		90		90		2.00		3		77.14
Living/kitchen/dining lights	3		9		27		4.00		7		108.00
Bath lighting	1		8		8		1.00		7		8.00
Compost toilet fan	1		18		18		0.50		7		9.00
Washing machine	1		325		325		0.50		1		23.21
Battery chargers for tools	3		36		108		0.25		2		7.71
Water pressure pump	1		80		80		0.25		7		20.00
Tablet charger	1		12		12		2.00		7		24.00
Smartphone charger	1		12		12		2.00		7		24.00
Utility room light	1		60		60		0.25		6		12.86
SHW pump	1		15		15		6.00		6		77.14
Inverter min. running power	1		10		10		24.00		7		240.00
Total AC Peak Loads (For Inverter Sizing)					785						
DC Load											
Refrigerator/freezer	1		55		55		8.00		7		440.00
										Total Avg. Daily Wh	1,151



Ben had already identified his anticipated loads on a PV system worksheet that I emailed him (see screenshot above and "Barthell System Loads" table, opposite page). The worksheet variables include the power consumption (in watts) of each electrical load, along with how many hours per day and days per week each load was operated. The spreadsheet then multiples the watts by hour usage per day to calculate each load's daily watt-hour energy consumption, then adds them up for a daily watt-hour total. After reviewing his spreadsheet, I suggested some changes to reduce his consumption, such as switching from compact fluorescent to LED lights. His largest loads would be refrigeration and an efficient clothes washer (Haier HLP28E, 2.3 ft.^{3}).

Allan Sindelar (2)

Space heating is accomplished with a small wood heater and some passive solar gain through a south-facing glass door. A 4-by-8-foot flat-plate solar collector provides most of his water heating. A propane-fired 15-gallon water heater provides backup.

Some loads, such as a fridge or water pump, must have energy available all the time. But a discretionary load is one that can be turned off or left unused when cloudy weather hits or your batteries are depleted. By identifying some household loads as discretionary during system design, the size and cost of the PV system can be substantially reduced. Your toaster oven, coffee maker, and clothes dryer are discretionary—when the batteries are at a low state of charge (SOC), use of these appliances can be curtailed.

Budgeting

An off-grid PV system's cost can vary greatly, since it depends on loads, lifestyle, and budget. A typical full-featured, professionally installed and code-compliant system for a common off-grid home can cost $15,000 to $25,000 (before incentives), including design, components, labor, building permit, and support. (That's usually a 1 to 2 kW array on a pole-mount, with a 3.5 to 8 kW inverter and flooded lead-acid batteries.) A small owner-installed system, even with some professional assistance, can meet more conservative budgets with quality hardware for as little as one-half of this amount. Knowing your budget range will help you keep your system in line with what you can afford.

Ben wanted to keep the entire system's costs under $9,000. The component package cost $7,000. System design, shop assembly, and programming added $250 in materials and $1,033 in labor.

BARTHELL SYSTEM COSTS

Item	Cost
8 Concorde SunXtender PVX-2240T, AGM sealed batteries	$3,019
Exeltech XP1100 inverter	1,130
System design, preassembly & programming	1,033
3 Aleo-Bosch 250 W PV modules	932
Morningstar TriStar MPPT 45 A controller & faceplate meter	662
Iota battery charger	445
MidNite Solar Mini DC panel disconnect & breakers	282
Shop preassembly materials	250
Rack (includes misc. hardware)	234
Shipping	217
TriMetric TM2020 system monitor	165
2 Battery interconnect cables, #2 x 12'	98
Meter box & shunt	45
Plywood mounting plate	17
Total Cost	$8,529
Federal tax credit (30%)	2,559
Net Cost	$5,970

Site-Specific Issues

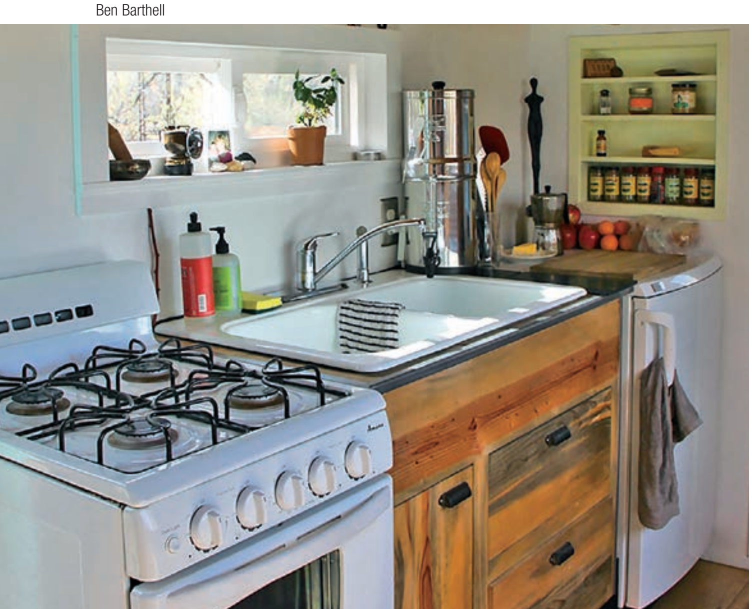
Select a site for your PV array that, ideally, remains unshaded all year, at minimum between the winter hours of 9 a.m. and 3 p.m. If you have a wooded or shaded site, consider using a site survey tool to determine one or more possible array sites. The Solar Pathfinder tool is simple to use and its sun path charts easy to understand.

An array that's located close to home is most economical (due to short wire runs), but up to several hundred feet away can work if that location has the best solar resource. Once you have determined the location, measure buried conduit and wire runs, select a location for the equipment and batteries, and plan your water supply (since your off-grid system will likely be powering at least one pump), choose and size your backup generator, and then formulate a plan for the installation.

Battery Voltage & DC vs. AC

Battery-based systems are nearly always 12, 24, or 48 volts. Although many novices assume that 12 V remains the off-grid standard, it offers little advantage except with vehicles that are already wired at 12 V and extremely small lighting-only systems. For whole-house systems, a higher DC voltage standard is usually better, with 48 V best for larger home systems and 24 V for smaller systems. Off-grid inverters are reliable and efficient, and with rare exceptions, I recommend conventional (and far less expensive) AC appliances and lights, as these allow standard household wiring. It's typically much easier to wire conventionally and use conventional (120 VAC) appliances and lighting in a home than to wire for and use DC appliances.

Ben Barthell



Ben already owned a SunDanzer DCRF134 DC refrigerator/freezer, which runs on 12 or 24 VDC, limiting voltage options. We selected a 24 V system, utilizing a step-down charge controller that could accept 90 V PV array input.

Ben's home was in a heavily treed area with relatively poor solar exposure among cottonwoods bordering the Rio Grande. I estimated an annual solar access value from shading of roughly 65%. A 4-by-8-foot utility room inside the tiny house provides enough space for a 15-gallon tank-style water heater mounted on a shelf, the washing machine, and a pressure pump. There was also enough room for the PV system components and eight 6 V batteries. He installed the array on an adjustable rack on his home's roof.

Allan Sindelar

Array & Charge Controllers

Today's common and cost-effective PV modules are 20 V at 250 W, with 60 cells. One- or two-array strings with two or three of these modules in each can provide 500 to 1,500 W, which works well for smaller systems. However, note that with a typical 29 to 31 V maximum power point (MPP), in some cases one 60-cell module won't adequately charge a 24 V battery bank—its MPP voltage will be too low to fully charge flooded lead-acid batteries during hot weather.

When choosing PV modules, look at the technology; how they attach to the rack; the voltage and current specifications; the UL (or equivalent) listing; the warranty; the manufacturer's longevity and reputation; and the price. Given the current competitiveness in the industry driving prices down, low price is the least important.

With the substantial drop in module prices over the last five years, off-grid system design has changed. In the early years, PV modules were expensive, batteries were cheap, and systems were designed accordingly. This cost relationship has now reversed, and a deliberately oversized array is more appropriate than a relatively large battery bank. This allows for more AC loads, more discretionary loads, and better battery care.

Your array should be sufficient to meet the expected daily load, plus recharge the batteries in one day of full sun, following several cloudy days. When possible, oversize your array to meet your average winter daily load, plus 25% to 50% of the battery bank's usable capacity. This means that a battery discharged to 70% DOD will be recharged in two to four days of average sun conditions.

An off-grid array is preferably mounted on a pole-top rack, as only this design allows for easy seasonal adjustment by one person to maximize gain. A less-expensive ground-mounted rack also allows for seasonal adjustment, but usually requires two people. But with lower module costs and an oversized array, a fixed rack, set 5° to 10° steeper than latitude, may provide sufficient charge all year, even in winter.

Charge controllers keep the batteries from being overcharged by the PV array and log data, and some can

After reviewing Ben's load analysis, we agreed that his consumption would be about 1,150 watt-hours per day in winter—the season of greatest use and least solar resource. We approximated that he would need a 500 W array just to keep up with his usage during the sunny high-desert winters. While the spreadsheet fine-tunes this calculation a bit more, to size the array, we divided his watt-hours per day requirement by 5.5 peak sun-hours per day (a conservative wintertime estimate based on NREL Redbook data), and then divided by a 0.65 derate value to account for system losses and a 0.65 solar access value: [(1,150 watt-hours/day ÷ 5 hours/day) ÷ 0.65 derate ÷ 0.65 shading deration = 495 W]. Two 250 W modules would provide the daily energy, along with minimal excess required to recharge depleted batteries after a cloudy stretch.

Given the minimal additional cost, we oversized the array by one additional module, to total 750 W in one string. Our logic was that this would be less expensive than upgrading his generator, which was undersized as a backup charging source. The increased array capacity would:

- Provide additional energy for those occasional times when needed, such as increased electricity loads due to guests or all-night projects, and for future load growth
- Preserve battery life, since batteries last longest when kept at a higher state of charge
- Minimize Ben's dependence on his generator, as the array could better maintain full battery charge during overcast weather.

Allan Sindelar

The roof rack and attached PV modules can be collapsed so that they sit parallel to the roof if and when the Steely Cottage needs to be moved.

divert surplus energy. Modern MPPT charge controllers can accept a higher array voltage to support a lower-voltage battery bank, so higher-wattage modules can work well in off-grid systems. Higher voltage allows smaller-gauge (and less expensive) wiring between the array and controller. Home-sized controller capacities range from 30 to 100 amps. An example 60 A rated MPPT charge controller handles up to three 250-watt modules for a 12 V battery, and up to six (in two strings) at 24 V. It's also a good idea to size a controller to allow for future array expansion. For example, a common 60 A charge controller is only modestly more expensive than a 45 A unit, but may allow an additional module string to be added in future years.

Battery Sizing

With a small home or cabin, a smaller battery bank is often desirable, especially with an oversized array, since it is more likely to get fully charged regularly. During sunny weather, the modules will finish recharging the battery earlier in the day. During cloudy periods, more PV production to boost the batteries means less reason to run the generator.

Days of autonomy (DOA) refers to the theoretical number of days that a battery could supply the total average daily load without recharging, usually to a minimum of 20% state of charge. In the Southwest, a bank sized to supply two to four DOA is plenty. In a cloudy winter climate, more DOA may be desirable, but upsizing the array may be a better choice.

For a seasonal cabin with unattended operation, sealed batteries may be worth the trade-off of substantially higher cost than their flooded lead-acid (FLA) counterparts. Consider them if you prefer not to do maintenance during periodic visits. Since cell-top access to add water is unnecessary, they can rest in any orientation without harm. Their stackability means they can occupy less floor space than flooded batteries.

Sealed batteries offer some benefits over flooded batteries. They require no maintenance beyond proper charging, and they don't gas during normal charging. They are charged with lower voltages and can tolerate small arrays and lower charge rates, as long as they regularly reach and maintain full charge. They don't require adding water or equalizing, plus they don't leak and won't foul battery storage areas or attract corrosion on terminals. As they are non-spillable and non-hazardous, they can be shipped via common freight with no hazardous material costs. But they also have their drawbacks. Sealed batteries may last longer than inexpensive flooded lead-acid batteries, but not as long as quality deep-cycle FLA batteries. Sealed batteries also are substantially more expensive and are more susceptible to damage from overcharging.

We determined that a battery bank of about 8 kilowatt-hours of storage capacity (to a 75% maximum depth of discharge) would provide four days of autonomy. We selected sealed lead-acid batteries, which fit the space in his mechanical room. Again, the spreadsheet offers a more detailed calculation, but here's the basic battery sizing calculation: [(1,150 watt-hours/day ÷ 0.65 efficiency losses) × 4 DOA) ÷ 0.8 DOD] = 8,850 Wh (~9 kWh). Real-world system efficiency losses differ between the DC loads (since there are no DC-to-AC inverting losses) and AC loads; this variance accounts for the slight difference in our calculation versus the spreadsheet. Also, in this sunny climate, the average depth of discharge is less than 20%.

web extras

"Off-Grid Batteries" • **homepower.com/140.82**

"Choosing the Best Batteries" • **homepower.com/127.80**

Sealed batteries are well-suited to homeowners who don't want to perform their own battery maintenance. This includes many newcomers to off-grid living, who want (and can afford) a professionally designed and installed system but prefer not to be involved with battery maintenance. They are also well-suited to cabins and homes with seasonal use and little maintenance, but be sure that the charge controller's settings are appropriate for sealed batteries.

Inverters

As most of us have multiple plug-in electronic devices, only use inverters with a pure sine waveform. The clean waveform allows sensitive electronics to run cooler and prolongs their life. Some electronic devices (for example, some chargers for cordless tools) will fail completely if powered by modified square wave inverters.

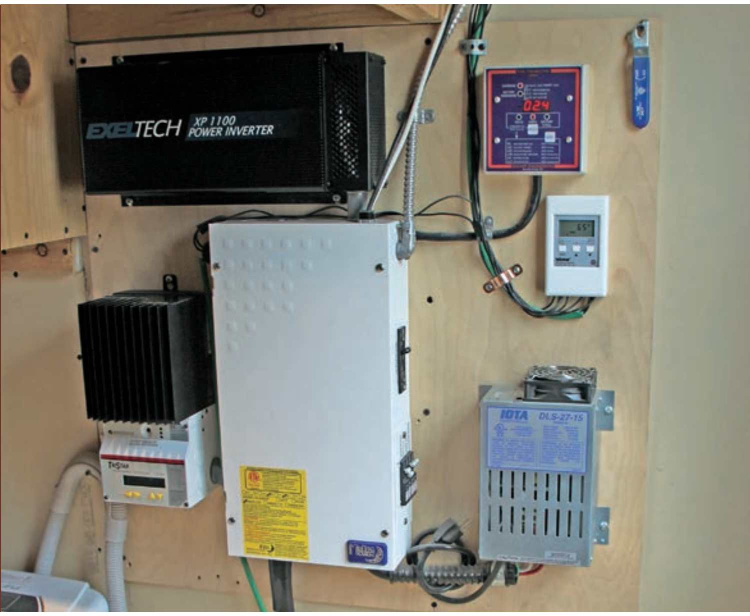
Three factors determine selection of inverter output capacity:

- The inverter's ability to run simultaneous loads, as determined by the load analysis.
- The needed surge capacity—the ability to start motor loads, such as power tools, pumps, or a refrigerator. (However, because most inverters surge to at least twice their rated output, this is seldom an issue.)
- The battery charging capacity, which is determined by the battery bank and backup generator's capacities. Sometimes a larger inverter is selected simply because it reduces generator runtime.

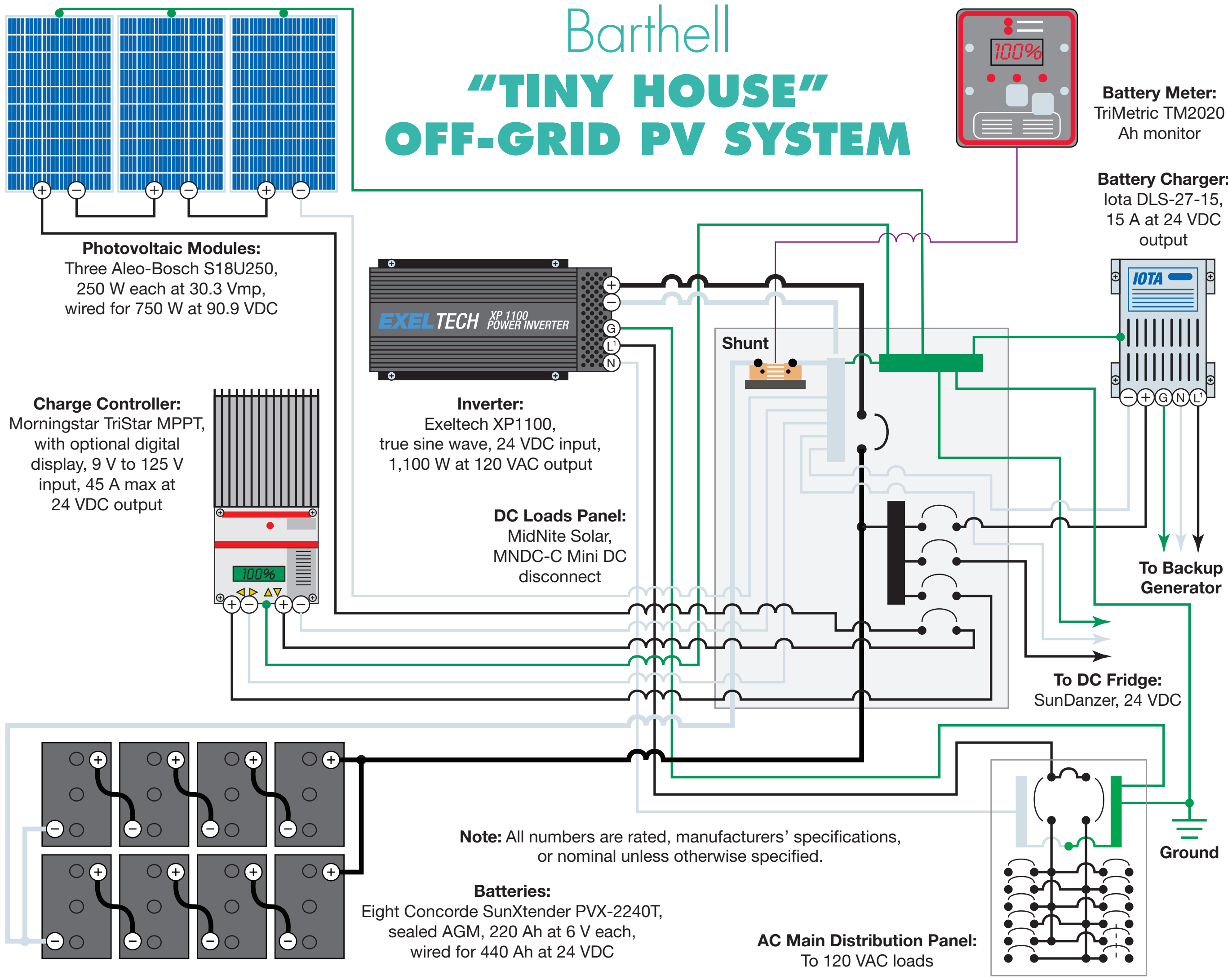
Allan Sindelar (2)

Neither of Ben's largest loads—the fridge nor the clothes washer—are particularly demanding to start and run, which allowed specifying a smaller inverter than would typically be needed for the loads of a larger home. Given Ben's use of multiple high-tech electronic devices, I chose a pure sine wave Exeltech XP inverter rated at 1,100 W, with the 10 W low-idle option to reduce the inverter's energy consumption when not in use. While most inverters have built-in battery charging capacity to allow battery charging from an AC power source, the Exeltech doesn't. Ben already had purchased a 1 kW generator, reduced by elevation effects to about 800 W, so I chose an Iota 15 A battery charger to match its output. With a maximum AC input of 788 watts at 120 VAC, this charger wouldn't overload his generator.

Having determined a system voltage of 24 V and inverter, array, and battery capacities, the BOS components were selected and assembled into an integrated system. I left out AC or DC lightning arrestors, figuring that, since the entire system is self-contained and well-grounded with no buried conductors, Ben's home is relatively protected from lightning-induced surge damage.



Barthell "TINY HOUSE" OFF-GRID PV SYSTEM



TECH SPECS

Overview

Project name: Barthell Steely Cottage

System type: Off-grid, battery-based solar-electric

Designer/Installer: Allan Sindelar, Positive Energy Solar; Ben Barthell

Date commissioned: August 2013

System location: Espanola, New Mexico

Latitude: 36°

Solar resource: 6.4 average daily peak sun-hours

Production: 60 AC kWh per month

Photovoltaics

Modules: Three Aleo-Bosch S185U250, 250 W STC, 30.3 Vmp, 37.5 Voc, 8.24 Imp, 8.76 Isc

Array: One, three-module series string, 750 W STC total, 90.9 Vmp, 112.5 Voc

Array disconnect: MidNite Solar MNEPV20, 20 A breaker

Array installation: DIY mounts installed on flat roof, 45° tilt

Energy Storage

Batteries: Eight Concorde SunXtender PVX-2240T, 6 VDC nominal, 220 Ah at 20-hour rate, sealed AGM

Battery bank: 24 VDC nominal, 440 Ah total

Battery/inverter disconnect: 100 A breaker

Balance of System

Charge controller: Morningstar TriStar TS-45, 45 A, MPPT, 150 VDC max. input voltage, 24 V nominal output voltage, with optional TriStar Meter-2

Inverter: Exeltech XP1100, 24 VDC nominal input, 120 VAC output

System performance metering: TriMetric TM2020

Generator: Honda 1 kW

Charger: Iota DLS-27-15, 15 A at 24 VDC

Allan Sindelar

"Allan put me through an exhaustive and detailed process to determine the best system application," says Ben. "After several discussions, he designed a fully self-contained PV system for me. The system was preassembled and programmed in his shop, ready for my installation."

Other than occasionally cleaning the PV modules of dust and snow, Ben says, the system is maintenance-free. Even on overcast days, it provides about 50% of the array capacity to the batteries.

Besides the obvious benefits of avoiding fossil fuels, generating his home's electrical energy and not worrying about power outages or utility bills has been gratifying. He says he will likely never go back to an on-grid lifestyle.

Generator

There are many advantages to including a backup generator. A generator can pay for itself, in that a smaller PV system can meet 80% to 90% of the home's needs (while the generator supports the rest), as compared to a larger (and more costly) PV system sized to meet 100% of the demand year-round. Additionally, cloudy periods longer than the DOA require generator backup charging. You may seldom—or never, as in Ben's case—run it, but it allows a smaller, less expensive battery bank, since you can get by with fewer days of autonomy. Also, the array provides only a slow charge, and FLA batteries last longer with a periodic charge called "equalization" to knock off sulfation hardened onto the internal battery plates, and to bring lower-performing cells up to level with the others. So generator charging is usually needed to achieve proper above-normal equalization voltages. Ben's batteries, as they are sealed, don't normally need equalization. If they do, it's achieved at a lower voltage.

Integration Hardware

Power centers are self-contained units that include circuit breakers, a meter shunt, and DC terminal buses—making the system easier to assemble. Most major inverter manufacturers make proprietary disconnect enclosures for their products. MidNite Solar doesn't manufacture an inverter of its own, but offers many power centers, called E-Panels, to fit other manufacturers' hardware. E-Panels mount the inverter on its hinged cover, allowing an entire single-inverter system to fit in a closet with a 32-inch door (slightly over the working clearance required by the *National Electrical Code*). A quality installation should also include temperature sensors on the battery bank, linked to the charge controller and inverter for temperature-compensated charging. It can include AC and DC lightning protection, and an enclosure for batteries, whether site-built or a manufactured cabinet. A system monitor that shows battery state of charge in "percent of full" is essential. It is best located in the living area, rather than out of sight with the power equipment.

In the roughly 40 years that remote homes have been PV-powered, homeowners' expectations have grown with system capabilities. The principles involved in designing and installing today's small system resemble those of whole-house systems in early years, but with far superior performance. By following the guidelines in this article, your system will likely perform well and last for many years with minimal trouble.

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Will New Hydrogen Cars Get Traction?

by Bradley Berman

Courtesy Toyota (2)

Above and below: The Toyota Mirai, a fuel-cell vehicle that runs on hydrogen, is scheduled to hit the streets this fall.

Despite few fueling stations to support a fuel cell vehicle, Toyota is scheduled to release its Mirai FCV this fall. Will hydrogen cars hit the highways or remain a (tail)pipe dream?

Driving an electric vehicle (EV) has advantages over a regular gasoline-engine car. EVs are quiet and smooth and they deliver more torque. But battery-powered cars present a greater ideal: You can fuel them from household current, ideally supplied by an on-site PV array, to allow you to "dump the pump."

A major drawback to pure EVs is their relatively limited driving range—about 85 miles per charge for the most popular electric cars like the Nissan Leaf. (Note: Upcoming models, like the Tesla Model 3 and the Chevrolet Bolt, are expected to get up to 200 miles per charge.) Despite the fact that the average U.S. motorist travels less than 40 miles a day, limited range keeps some consumers on the sidelines. And many apartment dwellers and others without a dedicated 240 V supply of electricity at their residence likely wouldn't even consider an EV. These obstacles have pushed several car companies to pursue a different approach to tailpipe-emissions-free electric driving—cars powered by fuel cells.

Enter H_2

From the outside, there's no difference between a hydrogen fuel vehicle and a gas-powered car. But most hydrogen-powered cars toss away an internal combustion engine and replace it with electric-chemical components—a fuel cell and an electric motor, plus (usually) a high-output battery that can provide supplemental power to the motor.

Think of a fuel cell as a different kind of battery—one that is fed with reactants and spits out electricity. An internal combustion engine is similarly fed with gasoline or diesel, which gets burned or combusted. But with a fuel cell, nothing is burned. That's why it's more efficient. There are no combustion losses or wasted heat. Instead, it transforms a chemical form of energy (hydrogen and oxygen) into electrical energy.

Courtesy Toyota (2)

The 2015 Mirai also can generate electricity to use as backup power for a home. When full, the Mirai's hydrogen tanks hold about 150 kilowatt-hours of energy.

Hydrogen gas stored in a tank travels through the fuel cell's channel (or plates) until it hits a membrane covered with a platinum catalyst. It then splits apart into protons and electrons. The protons pass through, but due to the properties of the catalyst, the electrons can't advance from the hydrogen side (the anode) to another plate on the other side containing oxygen (the cathode). So an electrical path is provided for them, handily routing them as electrical current to a motor. Meanwhile, on the cathode side, protons and electrons are reunited and, together with the oxygen, form water.

Hydrogen cars are essentially a different type of electric vehicle—one that uses electricity from the fuel cell for power. These vehicles are often considered hybrids, because they also have a small battery pack. That's part of the vehicle's efficiency strategy—like a Prius that uses a combination of gas and battery-derived energy, a car like the Toyota Mirai uses a blend of energy from both fuel cells and a battery pack.

Understanding what happens under the hood is less important than the driving experience. Fill up the tanks with about 300 miles' worth of gaseous hydrogen. Jump behind the wheel, step on the accelerator, and the car quietly zips forward like an electric car, emitting only water vapor from its tailpipe.

H_2 Backup at Home

Toyota is one of the companies betting big on fuel-cell vehicles (FCVs)—cars powered by hydrogen stored in gaseous form in high-pressure tanks, rather than by electricity stored in batteries. The Japanese automaker will begin selling the Mirai, which is capable of 300 miles of range and five-minute refueling, in fall 2015. In November 2014 in Newport Beach, California, I attended the official media unveiling of the Mirai—Japanese for "future." (Ironically, the long-standing joke used by hydrogen-power skeptics is that hydrogen is the fuel of the future…and always will be.)

Toyota Mirai Fuel-Cell System Components

Courtesy Toyota

The Mirai's interior is well-appointed, providing digital feedback about the car's operation.

Toyota officials compare its futuristic fuel cell car with the Prius, which was unveiled nearly 20 years ago. Then, the hybrid gas-electric Prius, viewed as an improbable science-fiction project, became a mainstream reality. Toyota is hoping the Mirai will become its next Prius.

Toyota has decided that the long-term future of transportation favors a "hydrogen society"—not one relying on battery-electric vehicles. Agree or not, Toyota is gung-ho on hydrogen. "Toyota made a decision. The fuel-cell car is going to be a big part of our future," John Hanson, a Toyota spokesman, told me last year. "That's the direction we're going, big time."

The 2015 Mirai's two onboard hydrogen tanks store about 150 kWh of electricity, which can also be used as a backup energy source at home. Adding this "power take-off" was part of the Mirai's design from the very beginning, according to Satoshi Ogiso, a Toyota managing officer. He told me that there is a similar function available for Toyota's hybrids (but only available in the Japanese market). "Every one of our hybrids has a generator," he says, "to make electricity from gasoline and use it for backup power at home or to contribute storage capacity to the grid. With fuel-cell vehicles, we can also get this electricity—and without harmful emissions [at the tailpipe]."

The car's electrical outlet is a CHAdeMO port—the same connector used for quick-charging many of today's electric cars. But in this case, the CHAdeMO coupler is used to export electricity, rather than for battery charging.

Gaseous hydrogen has greater energy density than EV batteries, enabling the longer range of a fuel-cell car, says Ogiso. This also favors hydrogen over batteries for stationary energy storage, as for buildings. He adds that batteries only last about five to 10 years, whereas longevity is not a concern when using tanks to store hydrogen. Tim Lipman, a hydrogen fuel-cell expert at UC Berkeley says that the hydrogen storage tanks should last the life of the vehicle—if not longer. Ogiso suggested that in a hydrogen society, cities will devote big spaces for storing hydrogen, with large tanks connected to facilities making hydrogen from solar, wind, and geothermal sources.

Honda is one of at least four other car manufacturers developing hydrogen fuel-cell vehicles; the list includes Hyundai, Mercedes-Benz, and General Motors—with many others conducting research and building concept cars. While Honda is at least a few months behind Toyota in selling its fuel-cell car, it's further along with its own H_2-to-electrical-energy conversion device. The "Power Exporter Concept" has a maximum output of 9 kilowatts, and Honda's fuel-cell car has the ability to store about the same amount of energy as the Toyota Mirai.

Hydrogen fill-ups are straightforward—not much different than refueling with gasoline (left). However, for now, filling stations are scarce (below).

Courtesy Toyota (2)

The Car

The Mirai and Prius have similar acceleration and handling. The 153-horsepower Mirai, which weighs 1,000 pounds more than the Prius, accelerates from 0 to 60 mph in a leisurely 9.0 seconds. The feel of the steering and suspension provide little feedback from the road. The Mirai powertrain might be a technomarvel, but any excitement about the car is counterbalanced by the bland driving experience.

Toyota engineers told me that the hydrogen fuel-cell technology doesn't inherently prohibit robust acceleration, but it's a matter of how the throttle is mapped. A vehicle reflects a set of trade-offs—for example, conserving energy for longer range might trump sports-car speed.

The Mirai makes unfamiliar whines and hisses. Unlike the rumble of an internal combustion car, the clatter of a diesel engine, or the muted whistle of an EV—all of which emit their sounds in direct proportion to amount of acceleration—the Mirai's whir starts strong as the car launches, but then fades. I suspect that I would get used to the asynchronous sound over time.

My favorite feature, other than the power takeoff, is an H_2O button on the dashboard to purge water—the car's only emission—from the fuel-cell stack. It usually dumps about one-third of a cup underneath the car.

On the inside, the interior has a quasi-luxury finish—and the car is loaded with high-tech features, like collision warning and adaptive cruise control. It all contributes to the Mirai's hefty price of $57,500, or $499 a month for a 36-month lease with $3,649 down payment. Only a few Mirais will hit the U.S. roads—200 to U.S. buyers through 2015, and 3,000 through 2016. Toyota expects that a recently expired federal tax credit, worth as much as $8,000, will be restored. There's a $5,000 rebate in California, the biggest anticipated market for the Mirai.

Toyota is also offering three years of free hydrogen fuel. This step is a matter of necessity for Toyota—given the uncertainty about when hydrogen fueling stations will be ready. Toyota's marketing plan is to sell the Mirai at dealerships only after a hydrogen station has been commissioned nearby. It will be a painstaking, step-by-step process. But Toyota's bet is long-term, to be played out over decades.

Free Fuel—If It's Available

The Toyota Mirai can store 300 miles' worth of driving in two onboard tanks—like slightly oversized scuba tanks. Compare this to a battery-powered electric vehicle, which would need a battery pack that's about as long and wide as the sedan's entire cabin to achieve a similar amount of range.

However, with virtually no established fueling infrastructure, the Mirai may remain parked on the sidelines. With hundreds of thousands of EVs on the road, with thousands of residential PV systems powering them, a hydrogen future seems like hype. More than a decade ago, Arnold Schwarzenegger, then California's governor, stepped out of a hydrogen-fueled Hummer, declaring that by 2010 the state would build a "hydrogen highway," with 150 to 200 fueling stations at 20-mile intervals along major highways. Five years later, there are only 10 hydrogen

Courtesy Audi

Courtesy Honda

Courtesy Hyundai

Courtesy Mercedes-Benz

The Mirai's cabin isn't much different than any other modern vehicle—all of the basic instruments are present.

Right: The PTO's CHAdeMO port is located in the trunk.

Courtesy Toyota (2)

refueling stations in the United States—not all of which have user-friendly retail fueling. All except one are in southern California.

Toyota planners like to quote a 2013 study by researchers at the University of California, Irvine, which speculated that, if 68 stations across California put in refueling stations, on average, a six-minute drive from the most likely buyers of a fuel-cell car, these stations would be profitable within a year or two of coming online. The geographic and business modeling are far from certain.

The questionable economics of building hydrogen stations, to the tune of about $1 million to $2 million per station—and the lack of stable fuel prices or even the means for precisely measuring and pricing gaseous hydrogen—makes it impossible for Toyota to answer questions about exactly how and where Mirai drivers will refuel.

Losses & More Losses

Advocates argue that hydrogen can be produced in a relatively "sustainable" manner by, for example, reforming landfill gas into hydrogen. But the majority of gaseous hydrogen comes from steam reformation of natural gas—which is increasingly being sourced from fracking operations, and is then shipped to filling stations via diesel-powered trucks. That kind of distribution is not nearly as efficient as transferring electricity to an EV charging station via the grid.

Lipman says, "Starting with natural gas as a fuel, it is much more efficient to distribute electricity through the main electrical grid than to take that same natural gas, make hydrogen through steam methane reformation, and then reconvert the purified H_2 back to electricity in a fuel cell in a vehicle."

Rudolf Krebs, Volkswagen's chief of vehicle electrification, agrees with Lipman. At the 2013 Los Angeles Auto Show, I spoke with him about the sustainability of fuel cell cars versus battery-electric vehicles. "Hydrogen mobility only makes sense [from an environmental perspective] if you use green energy [as a source]," says Krebs. That means using renewably made electricity, then converting it to hydrogen. But this conversion process is inefficient, with losses of about 40%. And then you have to compress the hydrogen to store it in the vehicle—and that reduces efficiency further.

Krebs says he thinks that the greenest *hydrogen* vehicle is a plug-in hydrogen hybrid—one that would operate on battery-stored electricity for most local miles, and only switch to hydrogen for longer trips. This concept is similar to how the Chevy Volt works, but using a fuel cell and an electric motor instead of gasoline and an internal combustion engine.

Sourcing H_2

Hydrogen is not a freely occurring resource—and making it is difficult as well as inefficient. Currently, steam reforming—combining high-temperature steam with natural gas—accounts for the majority of the hydrogen produced in the United States. And much of this natural gas is sourced via fracking—a disruptive process that's leaving highly polluted watersheds in its wake. (Estimates say that about 40% of California's natural gas production is from fracking operations.)

Hydrogen can also be produced from water through electrolysis, but this method is even more energy-intensive. Renewable sources of energy, such as wind or solar, can be used instead to produce hydrogen—avoiding harmful emissions from other kinds of energy production, but at large energy losses.

web extra

Informational videos from Toyota about how the fuel cell system works: **http://miraifcv.com/category/media/videos/** especially **http://miraifcv.com/2014/11/2016-toyota-mirai-fcv-fuel-cell-system/**

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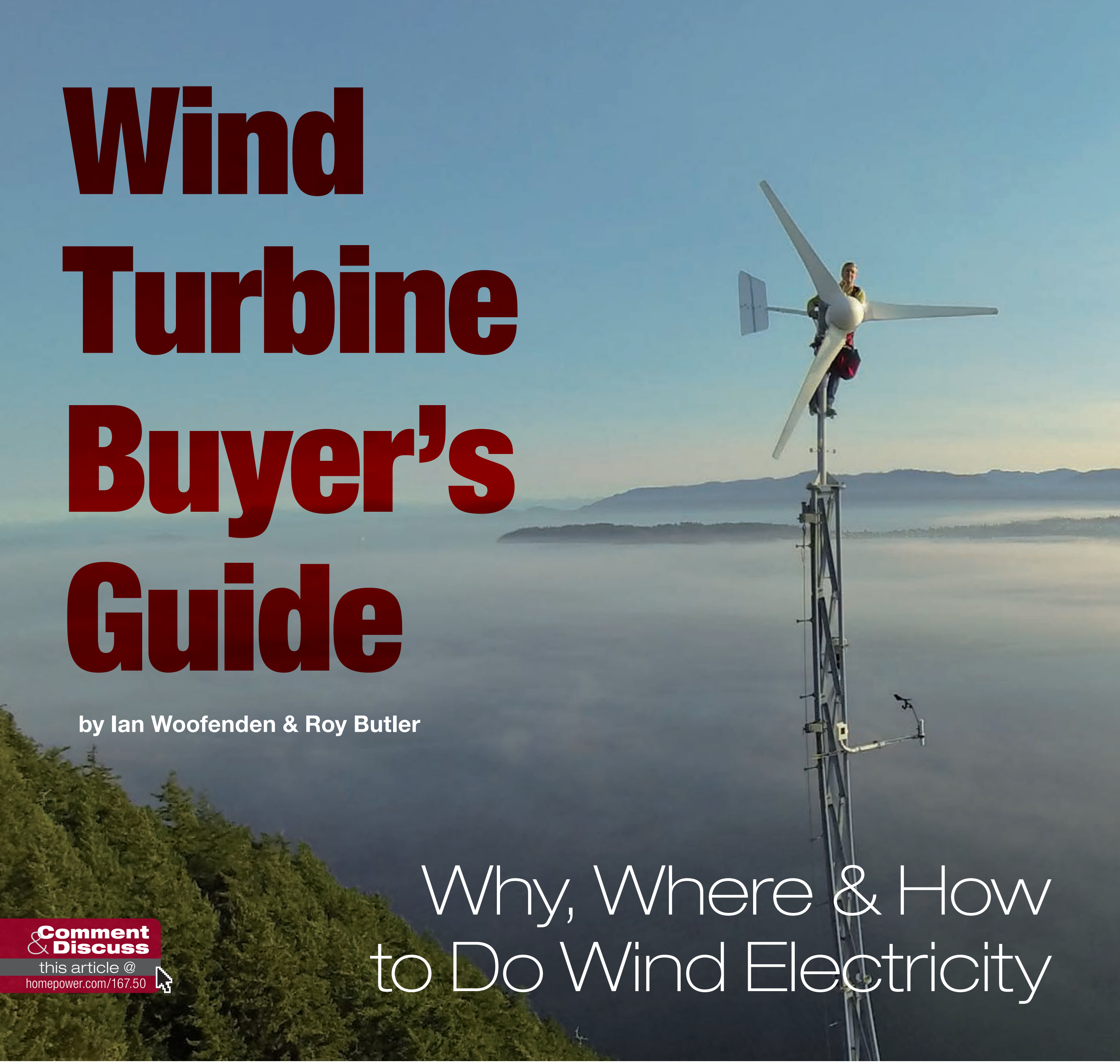


Wind Turbine Buyer's Guide

by Ian Woofenden & Roy Butler

Why, Where & How to Do Wind Electricity

Making electricity with the wind is not easy. As seasoned wind-energy installers with decades of experience, we—as well as thousands of others who live with home-scale wind turbines—tell a challenging tale. And the small wind industry today reflects those challenges, with long-established companies struggling and going under while the cost of reliable solar-electric modules continues to drop. If you think you want a wind-electric system, first think smart, then realistically.

Done well, residential-scale wind energy can provide clean kilowatt-hours in a very satisfying way. But because of the characteristics of the wind, wind systems have several strikes against them:

- Tall towers are required for meaningful production
- Reliability and robustness are hard to come by
- Compared to solar electricity, the cost per kWh can be high
- Qualified local installation and maintenance help is difficult to find
- Hype, misinformation, and outright scams are too common

This article will help you sift through the rhetoric and numbers, and make a wise decision about whether or not to tap local wind energy. If you decide that wind is right for your site, we want to help you understand how to make it work for the long term.

Roy Butler

For best performance, wind turbines need to be installed atop tall towers, which gives them access to less-turbulent winds.

Ian Woofenden

Towers need to be tall, tall, tall.

Mike Schmidt

Why Wind?

First, we suggest you get a handle on your motivations, needs, and situation. These will help determine whether a residential wind-electric system makes sense for you. People choose wind energy for several reasons, including:

- Environmental concerns
- Decreased cost of energy
- Desire for independence
- Fun and interest

Each of these motivations—and combinations of them—will lead to different choices. Be realistic about why you are considering wind energy and make sure the actual results satisfy your expectations and goals.

When installed correctly in the right location, a residential wind-electric system can produce cleaner energy than North America's utility grid, which is dominated by coal and other dirty energy sources. But a wind system needs to make significant energy (kilowatt-hours) for years or decades to make environmental and financial sense. Otherwise, you could end up spending a pile of money on an unproductive wind energy system—and still be shelling out dollars for that dirty coal energy you're using now.

Scrutinizing your real cost of wind energy is crucial if your primary goal is to save money. Many wind-electric

Ian Woofenden

Wind power systems require regular maintenance, which usually means routine climbs to the tower top.

systems are installed with unrealistic financial and durability projections, and end up generating energy that is more expensive than the local utility grid. A low cost per kWh requires a productive and long-lasting wind-electric system.

If independence is your goal, a reliable, long-lasting system is important. Otherwise, you will end up being dependent on the utility grid or worse—a fuel-fired generator.

Having a wind generator for a hobby and DIY project can be very satisfying—but requires having patience with the potential maintenance and failure in these systems. Some of our wind colleagues don't really mind when a wind turbine fails because "they get to build another one." Other people would be quite discouraged at the same situation. A large amount of patience and perseverance may be needed, depending on your budget and design decisions.

Most of these motivations require not only a firm grip on what a wind-electric system will do for you, but a clear idea of how much energy you use, and what form it is in. If your home is heated by gas or oil, you'll need to switch to electricity (we suggest minisplit heat pumps) to make an impact with your wind generator. Becoming energy literate and analyzing your home or business's energy use should be an early step in any renewable energy system design.

Whatever your motivation, do all you can to make sure your expectations of the system's costs, energy generation, longevity, and impacts are realistic. Do your homework, find local mentors and wind energy users, and make wise purchase choices so you end up satisfied—instead of disillusioned.

Where is the Wind?

Getting an honest answer to the question, "Where do wind generators work?" could save a lot of people a lot of disappointment. The obvious answer is, "Where there is wind!" Unfortunately, many people are ignorant of or blind to the details behind this simple answer.

Wind energy is cubic—the energy in the wind increases with the cube of the wind speed. This means that a 20 mph wind has 8 times as much energy as a 10 mph wind. Even a small increase in wind speed yields a significant increase in energy potential. For example, going from 12 mph to 15 mph almost doubles the wind energy potential.

But just like trying to move water in a pipe or a rope through a pulley, friction is wind's enemy. In the case of wind, it's the drag imposed by trees, buildings, and landforms that robs the energy in the wind. The reality is that there just is not much wind energy left once it travels close to these obstructions.

In flat, open terrain, a shorter tower can suffice, although it still needs to be high enough to put the turbine in "clean" winds.

Courtesy Mark & Vivian Williams

In rugged terrain and/or trees, towers need to be significantly taller than surrounding obstacles.

Ian Woofenden

"Friction" and turbulence from ground obstructions reduces the annual energy output (AEO; see table) of any wind turbine. The farther above these obstructions your wind turbine is, the more wind energy there is. So wind energy experts frequently recommend taller towers. This is not because they have stock in tower companies, but because they understand wind physics.

There are some devilish details. A turbine on a taller tower will always capture more wind energy, but it's more important in some situations than others. We would not recommend a tower for *any* site be shorter than 60 feet, regardless of the terrain. But getting above the obstruction is somewhat less important if that obstruction is smooth, like a wheat field, tundra, or open water. "Wind shear" (the rate of wind increase as you rise above the earth) studies show us that wind speed increases more quickly above cities and forests than above open fields and water.

So what does a good—or bad—wind site look like? One analysis involves getting a view in your mind's eye from the tower top. At that height, if you can get a very distant and broad view without obstructions, you have one crucial component of a good wind site—access to unobstructed wind. But if you're "seeing" treetops, buildings, hillsides, and such, you aren't yet at the optimum height.

So hilltops, ridges, plains, and oceanfront settings top the list of good wind sites. Forests, deep river valleys, cities and suburbs, and other complicated and uneven sites are challenged by their basic topography.

Beyond getting above the obstructions, you need a site that experiences significant wind. While we frequently hear people say things like, "It blows 20 mph constantly," this is never true—personal observations of how much wind there is are useless in most cases. What's needed is actual measurement or studied estimation based on measured sites. This information is not always easy to obtain, and many wind turbines are sited without good data. If you decide to go ahead without hard numbers, you need to realize that you're taking a calculated risk—investing based on an educated guess of your wind resource. You may find wind data from local wind-energy users, meteorological sites, and, possibly, from utility-scale wind siting services.

It's also crucial to understand the difference between instantaneous and average wind speeds. While knowing the maximum instantaneous wind speed is useful to consider the durability and longevity of a turbine, instantaneous measurements are otherwise unimportant. What we really want to know is the *average* wind speed, from which we can calculate or determine a wind generator's energy production potential. Real-world average wind speeds at residential sites range from a barely-adequate-for-off-grid 6 mph to a rare high of about 14 mph on a site that is so windy you might not enjoy living there.

Fully understanding wind physics, and the science and art of wind-system siting, will spare you wasted money and unfulfilled dreams. Don't apply magical thinking to wind-electric systems—apply (or find an expert to apply) the math of wind to the physics of your site and make a tough-minded decision about whether you have the resource to fulfill your purposes.

Hybrid Off-Grid System Meets Winter Needs

We live on an off-grid 32-acre homestead in mid-coast Maine. Our electricity comes from a mix of solar-electric modules (990 W) and a Pika T-701 wind turbine. The PV array is mounted on a small outbuilding and feeds into a 24 V battery pack of eight Rolls-Surrette S-480 batteries through an OutBack Power MX-60 charge controller. The Pika turbine is mounted on a 107-foot NRG meteorological tower and feeds the battery bank through Pika's REcharge charge controller. Electricity is delivered to the house as 24 VDC and as AC from a Trace inverter.

We live on a hill and generally have a breeze. Before installing the wind system, the short and often cloudy days of winter meant that we had to run our generator frequently to keep the battery pack healthy. Pull-starting a generator on cold days, bringing in gasoline on a sled, and a general aversion to using gasoline-based power had us looking for renewable ways to provide energy during the winter. We approached Pika about a turbine, hoping that its off-grid system would work for us. It has worked better than we hoped, and is now our primary source of power.

Brent & Erin Bibles • Unity, Maine

Courtesy Brent & Erin Bibles

Net-Metered Wind Energy

We've known that we wanted a wind generator since we moved to Genesee County 13 years ago. The wind resource proved good based on the site survey and our rural location lends itself to the project. Nevertheless, it took us three years of dealing with local authorities to get permission. I then worked with the local planning board to rewrite the zoning law to allow personal turbines in our community.

Our system is a Bergey 5 kW (now sold as a 6 kW) on a freestanding 100-foot tower. It has a rotor diameter of 20 feet and is connected to the grid for net metering. We purchased it through Niagara Wind & Solar, and it produces more electricity than we use.

Mark & Vivian Williams • Alabama, New York

Courtesy Mark & Vivian Williams

Steps to Wind

If you've figured out why you want to try to capture wind energy, and you've determined that you have good wind potential at your site, what are the next steps to producing energy? Each wind system is different, depending on the site, tower choice, system configuration, installer, and owner, but this general list of steps will give you an idea of what you will need to do:

- System design
- Tower specification
- Permitting
- Soil analysis
- Excavation for tower base (all towers) and anchors (guyed towers)
- Concrete for base and anchors
- Tower assembly and installation
- Tower "tuning"—tension and plumb (guyed towers)
- Transmission and anemometry wiring
- Turbine installation
- Balance of systems and installation—electronic controls, batteries if needed, monitoring, etc.
- Commissioning and testing
- Maintenance plan
- Utility interconnection application and inspection (grid-tied systems)

Each of these items could be explained in several articles or a short book—though it's not rocket science, it's also not as simple as digging a ditch. At each step, someone needs to have a thorough understanding of the goals and challenges; the equipment that's available; and how to specify, integrate, and install it properly.

The turbine is only part of the system mechanics and cost.

Ian Woofenden

The larger the turbine and tower, the more infrastructure involved.

Courtesy Mark & Vivian Williams

Doing this yourself means you need to be a very handy person, willing to learn from the experience of others, and willing to get dirty. Otherwise, you'll need to hire contractors for the various parts of the task. Finding experienced wind help may be difficult in your area, but worth the effort, because you do not want to work with a company that is experimenting with your money, or worse.

Whether you or a contractor does the job, you'll need to get your gear from somewhere. We recommend you buy equipment from companies that have been around the block with wind energy, and those with a strong record of customer support. It's hard to put a value on the ability to make a phone call and get good information, replacement parts in a hurry, or analysis of a pressing problem.

The Good, the Bad...

So what distinguishes good systems from bad systems? It's not easy to make broad generalizations about the various types and configurations of wind-electric systems. But it's fairly safe to say that all good installations have these attributes:

- Sited where there is sufficient wind resource
- Turbine installed well above (30+ feet) all obstructions within 500 feet, minimum
- Engineered tower installed to spec
- Properly specified components matched to each other
- Excellent and user-friendly wind and wind turbine monitoring systems installed
- Clear maintenance plan

As a result, these less technical but no less important attributes will follow:

- Happy system owners and neighbors
- Energy production within owners' and installers' expectations/predictions
- Modest noise and visual impact
- Owners understand system or have easy access to experienced support

The people who are disappointed with their wind systems tend to have short towers, low-budget and mismatched equipment from newer companies or importers, and installation by inexperienced people. Most have unrealistic expectations of the wind resource and wind systems. These installations have high failure rates and low energy production. We've seen many systems that rarely generate any energy—and a system that costs even as little as $20,000 to as much as $100,000, but only generates a handful of kWh, is making *very* expensive electricity.

Wind Turbines Table

It was difficult to choose which wind turbines to include in this article. We start with a set of criteria, and try to apply them responsibly, but with some flexibility. Our goal is to give our readers solid information to make wise buying decisions, while being fair to manufacturers.

Included in our criteria is: sales and support in North America, warranty, certification (if applicable), price, and the company's longevity. We recommend that you only consider wind turbines with these basic qualifications. It's surprising how many people get into trouble by falling for hype about new concepts or from product promoters. Watch out for importers of gear not fully supported in North America, and companies that have more marketing than customer service.

We believe that the listed turbines offer the best opportunity to tap your wind energy. Some companies and machines are much newer than others, and are on the edge of our criteria; we encourage you to pay attention to time in business and in production when looking at the specs. The table that follows includes the following fields.

Wind in Wyoming

J Bar 9 Ranch is small cattle ranch where we raise hay and keep pasture for 150 to 200 cattle and 30 horses. The local herds of elk, deer, and sheep also use the pastures and hay meadows for winter forage. We have solar, wind, and just finished putting in two small microhydro units. The three renewable sources supply our electricity needs for the irrigation systems and numerous buildings.

Our main source of renewable energy is the Northern Power 100B wind turbine. The machine is a 100 kW direct-drive turbine with a 68.8-foot rotor, on a 98-foot tower. We had it factory-painted to "blend in" with the surroundings. We finished installing the turbine in October 2011. Since then, it has produced 655,735 kWh.

We chose the Northern Power 100B because our research showed it to be a very reliable and simple machine. The support and availability of parts for maintenance on the turbine was also a huge deciding factor. Northern Power has a great monitoring system that can identify problems quickly and efficiently.

Bob Curtis, J Bar 9 Ranch • Cody, Wyoming

Courtesy Bob Curtis

Wind Turbine Buyer's Guide

Turbine	In Business (Yrs.)	In Production (Yrs.)	Warranty (Yrs.)	Rotor Swept Area (Ft.^{2})	Rotor Diameter (Ft.)	Tower-Top Weight (Lbs.)	Certification
Bergey Excel 1 bergey.com	38	15	5	53	8.2	75	—
Luminous Whisper 200 luminousrenewable.com	8	6	2	64	9	66	IEC-61400
Pika T 701 pika-energy.com	6	1	5	76	9.8	93	Power Cert. in process[2]
Xzeres Skystream 3.7 xzeres.com	5	2	5	117	12	170	AWEA 9.1
Luminous Whisper 500 luminousrenewable.com	8	6	2	177	15	154	—
Luminous Whisper 500+ luminousrenewable.com	8	6	2	177	15	154	—
Luminous Windistar 4500 luminousrenewable.com	2	2	2	177	15	249	In process
Weaver 5 weaverwindenergy.com	5	1	5	210	16.3	821	In process
Bergey Excel 6 bergey.com	38	3	5	325	20.2	772	AWEA 9.1
Ventera VT-10 venterawind.com	10	7.5	5	380	22	580	In process
Bergey Excel 10 bergey.com	38	32	10	414	23	1,200	AWEA 9.1
Bergey Excel R bergey.com	38	32	10	414	23	1,200	—
Xzeres 442SR xzeres.com	5	4	10 turbine, 5 controller	442	23.6	1,600	AWEA 9.1
Wind Turbine Industries Jacobs 31-20 wind-turbine.net	29	30	5	755	31	2,000	Certified Power
Osiris 10 osirisenergy-usa.com	8	6	5	797	31.8	1,870	AWEA 9.1, IEC 61400-2
Eocycle 25 eocycle.com	14	5	2, with 5 ext.	1,347	41.3	4,960	In process
Endurance Wind Power E-3120 endurancewindpower.com	8	6	5	3,120	63	8,800	Certified Power[1, 2]
Northern Power NPS-100C-24 northernpower.com	41	16 (NPS100)	2	4,867	78.74	15,300	—

[1]AWEA standards do not cover turbines this size—only up to 2,153 ft.^{2} (200 m^2). [2]The turbine power curve has been certified to industry standards by a nationally recognized testing facility.

Manufacturer website is your first source of information. Take the time to read through the content thoroughly, including the fine print.

Years in business may tell you about the reliability of the machines and the company behind them, as well as capability of keeping wind turbines and a business support structure alive.

Years model in production tells you how long the model has been manufactured, and may be an indication of its level of development and reliability.

Warranty is an important factor in choosing a machine because it protects you in the case of failure due to design and workmanship, and because it may indicate the manufacturer's confidence in the machine. Read the fine print to be clear on what is—and is not—covered. Usually it's parts, but not repair or replacement labor.

Rotor swept area is the collection area of a wind generator—the basis of the quantity of energy it can capture. No other specification has more to do with a wind generator's production.

Rotor diameter is another way to indicate the swept area, but it's deceptive because area is proportional to the square of the diameter.

Tower-top weight may give you some indication of a machine's robustness, since heavier machines may be more durable, and also is important to know for tower specification.

Rated Power @ 11 m/s (kW)	AEO @ 5 m/s (kWh)	Est. Annual Energy Output (AEO in kWh) for Wind Speeds 8 mph	9 mph	10 mph	11 mph	12 mph	13 mph	14 mph	AEO Source	RPM @ Rated Power	Governing System	Governing Wind Speed (mph)	Cost (Turbine & Controls)
1.00	1,110	420	610	840	1,180	1,400	1,710	2,040	Mfr.: Windcad	490	Furling	29	$4,595
0.99	2,052	871	1,231	1,629	2,048	2,473	2,890	3,291	Mfr.	1200	Furling, dump	31	3,291
1.50	2,420	700	1,250	1,800	2,350	2,900	3,500	4,100	Mfr.	400	Stall	53.7	6,675
2.10	3,420	989	1,740	2,576	3,282	4,115	4,962	5,814	Mfr.	330	Dynamic brake	27	Call
3.10	5,568	2,309	3,286	4,386	5,572	6,803	8,042	9,256	Mfr.	800	Furling, dump	31	7,296
3.15	5,846	2,424	3,450	4,605	5,850	7,143	8,445	9,718	Mfr.	650	Furling, dump	31	8,040
4.31	7,800	2,724	4,800	6,900	7,800	9,600	12,000	14,400	Mfr.	450	Furling, dump	31	9,466
3.85	3,857 – 4,897	1,647 – 2,096	2,312 – 3,033	2,945 – 4,085	3,496 – 5,172	3,944 – 6,213	4,290 – 7,142	4,546 – 7,919	Mfr.	260	Active furling	50	38,576 – 62,190
5.50	9,920	3,963	5,582	7,470	9,536	11,667	13,850	16,325	Mfr.: Windcad	400	Furling	31 – 45	21,995
9.30	12,772	5,037	7,218	8,957	11,625	13,924	17,599	20,836	Mfr.	280	Blade pitching	28	24,000
8.90	13,800	4,924	7,124	9,850	13,026	16,499	20,248	24,712	Mfr.: Windcad	400	Furling	31 – 45	31,770
7.50	13,800	4,549	6,723	9,292	12,114	15,008	17,922	21,125	Mfr.: Windcad	400	Furling	31 – 45	26,870
9.17	15,329	4,990	8,583	12,630	16,017	19,958	23,984	27,997	Mfr.	150	Dynamic brake	26	Call
12.00	16,630	5,100 – 7,800	7,450 – 11,375	10,420 – 15,900	13,900 – 21,225	17,742 – 2,7075	21,950 – 33,470	26,250 – 38,950	Mfr.	175 – 185	Blade pitching, furling	30 – 45	53,550
10.00	23,704	8,250	13,929	18,824	22,740	27,530	31,340	35,734	Mfr.	120	Passive & active pitch	20	27,500
23.00	37,229	11,230	18,992	25,625	34,160	44,471	53,775	64,700	Mfr.	90	Stall, active yaw	56	81,000
56.80	116,935	41,516	65,214	88,913	112,611	137,334	162,289	186,458	Mfr.	42	Stall control, air brakes	56	215,000
90.20	196,000	80,000	113,000	150,000	189,000	228,000	267,000	305,000	Mfr.	50	Stall control	56	365,000

Certification lends credibility to a machine, showing that it has gone through a standardized testing process. Some established manufacturers choose to avoid the expense and time of certification, and certification is not a direct measure of longevity in the field, which is more important than peak performance. The Small Wind Certification Council (SWCC) and Intertek are the primary North American players in the small wind certification field. They assure that the turbines are tested to U.S. and international standards, verify the accuracy of the testing data, and then issue full certification or power curve certification.

AWEA rated power at 11 m/s (25 mph) average wind speed is a standardized power rating that may be handy for comparison, but is not particularly useful beyond that, and can be deceptive.

AWEA rated AEO (annual energy output) at 5 m/s (11 mph) average wind speed is a standardized energy rating, and can be cautiously used to compare turbines—but won't relate directly to your site unless you also happen to have a 5 m/s average wind speed.

Estimated AEO at 8 through 14 mph is predicted energy production at the average wind speeds most common at residential sites (14 mph and above are rare). These are important specs because they relate to *your* site. This specification also demonstrates the crucial need for good average wind speed measurement or calculations for your tower top.

AEO source identifies the source of the AEO numbers.

web extras

For more wind system strategies, see the following articles:

"Understanding Wind Speed" by Ian Woofenden in *HP143* • **homepower.com/143.106**

"How a Wind Turbine Works" by Ian Woofenden in *HP148* • **homepower.com/148.46**

"Wind-Electric System Maintenance" by Roy Butler & Ian Woofenden in *HP135* • **homepower.com/135.98**

Rpm at rated power identifies the rotational speed of the turbine and is a useful comparative number between machines of about the same rotor diameter. In general, lower rpm machines are longer-lived, with less wear and tear and lower noise levels.

Governing system specifies the method of controlling overspeed, a crucial design factor for all turbines. High winds pack a punch that needs to be avoided—not absorbed. Without a reliable governing system, your turbine will sooner or later break; with one, it will continue to make energy during and after high wind events.

Governing wind speed at which a machine is fully governed—protected from high winds and the overspeed conditions they can cause. A low governing wind speed is more likely to indicate a long-lasting machine.

Cost typically includes turbine and controls, but we recommend looking carefully at exactly what is included in each package—and what else you will need to make a complete system.

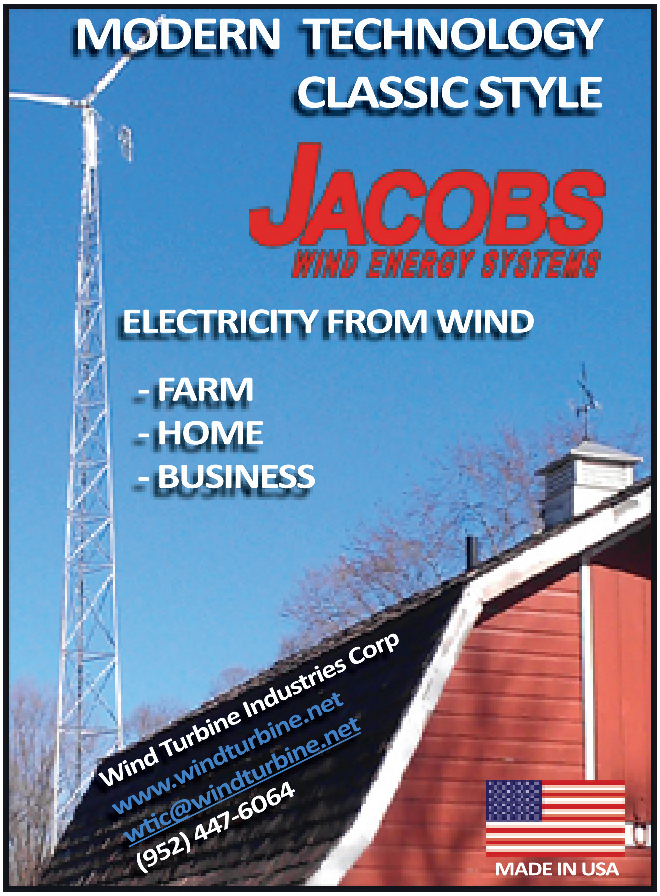
Pessimistic—or Realistic?

We, the authors, both love wind power, and have lived with it, written about it, and taught it for many years. At times, we are accused of being negative about our own field. Both of us have lived with failures in our own wind systems and those of clients, friends, and neighbors. We've come to our own levels of realism about what wind energy can and can't do, and how to approach it to get the desired results.

We are definitely skeptical about manufacturer hype; light-duty machines; missing or mis-information; and untested schemes, claims, and machines. We are negative about false claims, deceptive advertising, poor support, and marketing that doesn't reflect reality. No matter how well the turbine is engineered, it cannot change the physics of the wind.

At the same time, we are exuberantly positive about machines that are well-tested in the field and have realistic ratings and good track records. We're excited about manufacturers that take care of their customers. And we're delighted to hear stories from end users that are not horrific, but tell us of energy generated and used, appreciative instead of irritated neighbors, and expected reliability and production.

Take your time approaching wind energy. It's not a quick fix, and it's definitely not for everyone. But if you have a good site, an appropriate budget, plenty of knowledge and support, and a good attitude, you can make a wind generator successfully fly over your property. It's hard to tell you in writing the level of satisfaction that can bring, but you could be the next person to have that wind generator smile.



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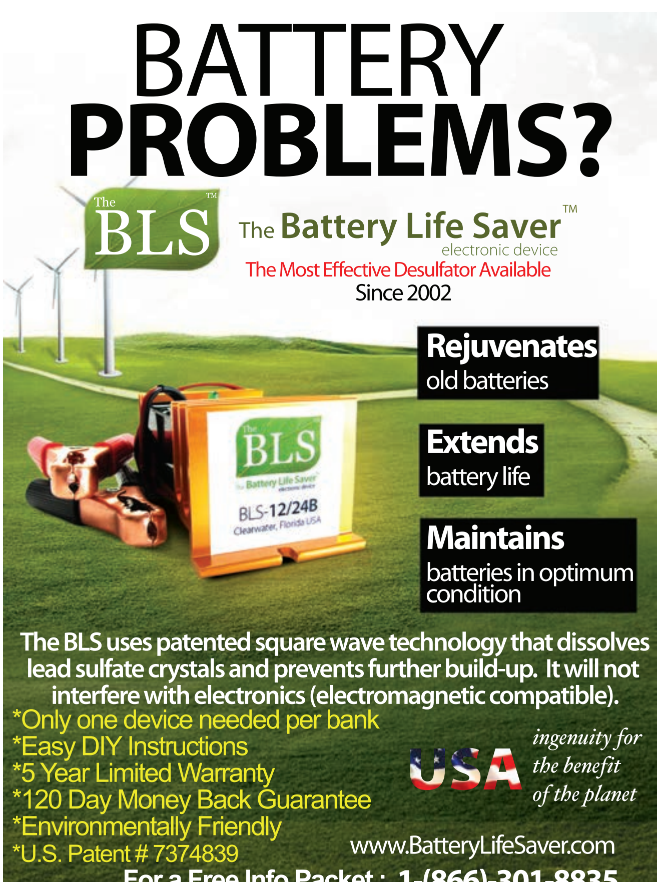

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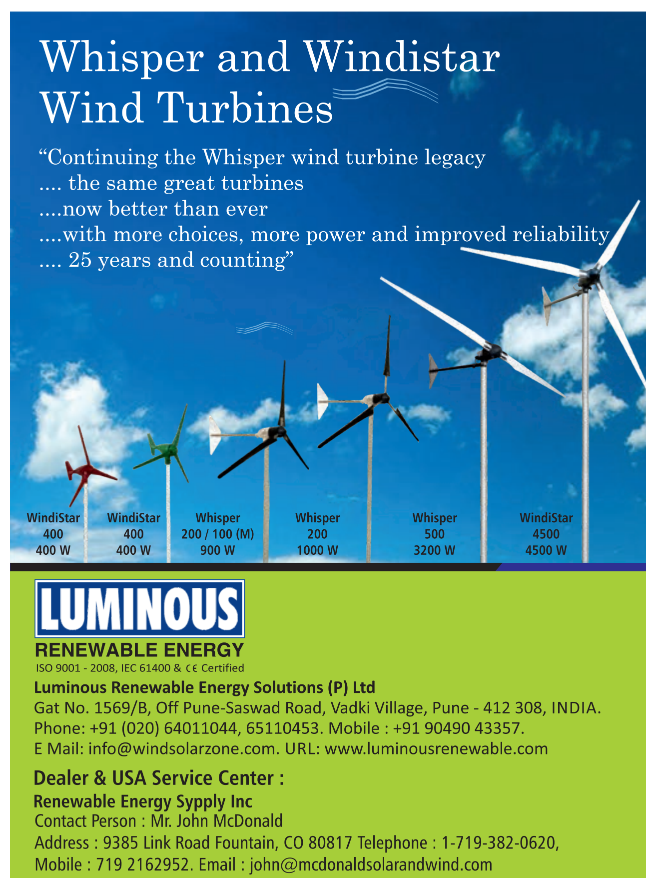

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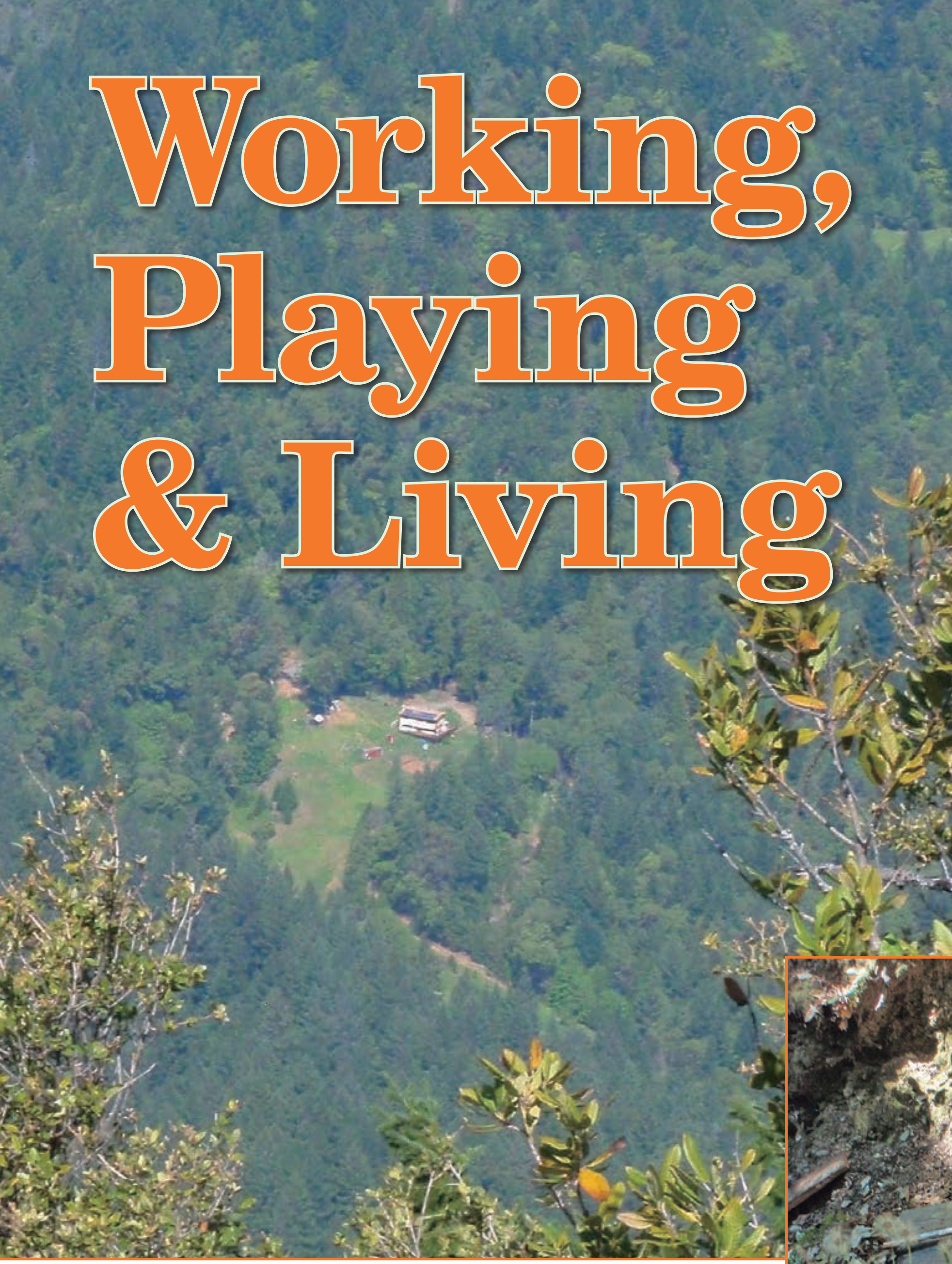


Working, Playing & Living ...with Renewable Energy

Story & photos by
Penny & David Eckert

Dave Eckert in the spring box that supplies potable water, irrigation, and hydro power to their homestead a mile away.

Our RE system is more a testimony to a lifelong interest in energy alternatives and experimentation—always looking for the ideal system—than it is to rational, market-driven decision-making. We enjoy experimenting, trying everything, discarding many things, and continuing with what works best for our household. We have funded this passion with two full-time jobs over the years, and find that the investment provides delightful dividends in knowledge and independence.

First Electricity

David—In 1975, I was working on a logging crew up a steep logging road in the Pacific Crest range of northern California, near the town of Orleans. As the crew traveled the rough old road, we bounced over rocks and dodged logging trucks. On the way home, we'd often stop at a reliable spring, where we would drink some water and wash off the worst of the dust before loading back up in the "crummy" to continue making our way down the hill.

There was a bit of private property along the way—below that spring and above a river—that had some potential as a homestead site. I found the owner and bought 80 acres in 1976 for $20,000. It was cheap because the potential building sites were all above the two seasonal springs on the place, and water would always be an issue. But I kept thinking about that deep, reliable spring on the old road, and I started clearing a little bit of land for a building site, in between jobs and when I was laid off for the winter.

In 1976, by the time I wanted to develop that spring as a water source for my place, the Forest Service had abandoned the rocky old road in favor of a paved route that more closely hugged the ridge. They ripped up the old roadbed as best they could, which meant that it was available to lay my water line from the spring to my place. Though it was full of rocks and went through some really nasty bedrock, it had a fairly steady slope.

I got some friends together, put some beer on ice, and with my 1946 bulldozer, plowed a trench along the old road, rocks and all. We laid 5,000 feet of 1 1/2-inch PVC pipe in that trench from the spring all the way down to a saddle. The waterline then dropped fast across my property, barely buried, until it reached our building site.

Penny—Getting permits to use this water was not easy. David had started this process for the first domestic water right before I met him. In fact, I met David in 1979 when he was applying for a minor change to his special-use permit to cross National Forest with his waterline. I was fresh out of the Peace Corps and new to the U.S. Forest Service (USFS). I came out to review the waterline, revised the special use permit—and married David about 18 months later.

Soon after we were married, I worked to develop a water right for a hydroelectric system to capture the winter high flows from the spring. Later, I pursued a separate irrigation water right for our "lower flat" area. We also ended up with an official number from the Federal Energy Regulatory Commission (FERC) as exempt from licensing for our hydroelectric project. Because I worked for the USFS, some extra effort was required to become a co-owner in the property and the water line because of conflict of interest issues surrounding the Special Use Permit to cross National Forest. We now file papers annually with FERC and pay for all three water rights with the State of California. We periodically pay the USFS for the privilege of crossing National Forest to convey essential water to our homestead. These fees add up to about $500 per year for the privilege of owning and maintaining our own water and power systems.

The House

Penny—With reliable water and a little bit of power from our first hydroelectric system, we built an off-grid house in 1981. Thanks to our wonderful architect, Hachiro Yuasa, we have a passive solar house that absorbs solar energy during winter and minimizes heat gain in the summer. It's nothing fancy—a south-facing stick-built house built into a slope, with a fully insulated walk-in basement under the eastern half of the house and two full stories above—but thoughtfully designed to take advantage of the site and the winter solar gain.

The house has an R-30 ceiling, and we bought double-pane windows back when they were still a novelty. A large expanse of windows is on the east and south-facing walls. In the winter, the sun's rays reach the center of the house. The east windows and a sliding glass door on the east side are also critical for solar gain in the spring and fall. In the summer, the sun angle is high enough that roll-out canopies entirely shade the south windows; roll-down shades shade the eastern windows, eliminating solar gain when we don't want it.

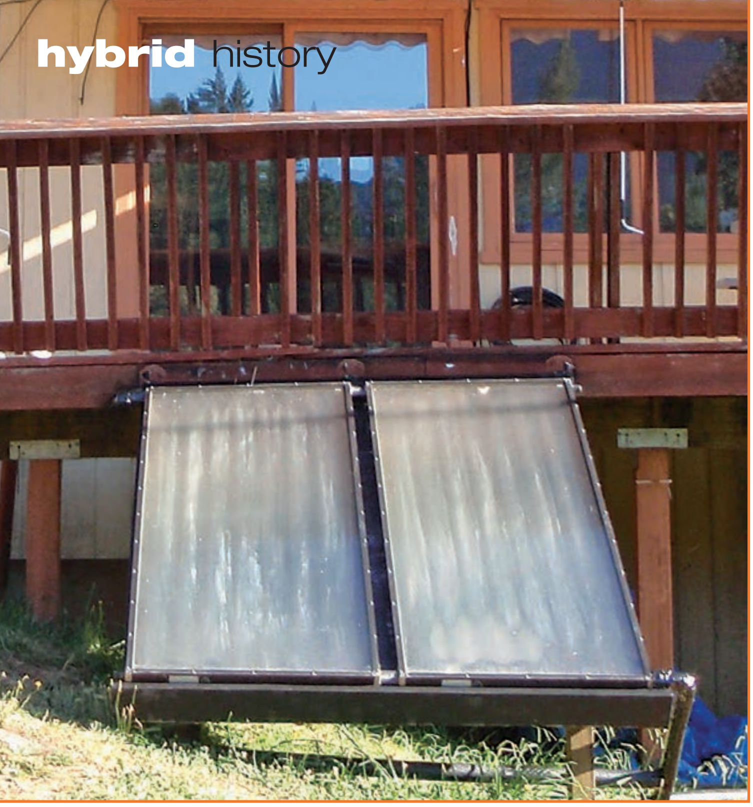
Simple and solar: passive design and energy efficiency combine with renewable energy for off-grid, country living.

A whole-house fan helps cool the house on summer evenings. A solar clothes dryer (aka clothesline) is used from May through September. We converted all the lighting from incandescent to compact fluorescent, then to LED, over a three-year period. As of 2014, our home uses LEDs exclusively.

Renewable Heating Systems

For eight years, we used a pair of solar collectors—two 3-by-7-foot Grumman Sunstream—to preheat our domestic water. Connected in parallel, they were plumbed to the electric water heater on the first floor. The system included a pump to move the water to the tank, and a Goldline C-30 differential temperature controller. In 1990, when we were preparing to leave for work in the Dominican Republic and needed to make the house easy to operate for a caretaker, we switched from electric to propane for water heating and decommissioned the solar water heating system, using its path down from the roof to the water heater for a vent for the propane heater. Although we had drained it, the system suffered some freeze damage.

David built a wood-fired furnace from scratch in 1981, using salvaged steel, and included a large water jacket in the design. During the winter, heated water from the furnace thermosiphoned to the water heater tank on the first floor—we used virtually no other fuel to heat water. Although we had to



Solar thermal collectors, brought back online recently, reduce the run time of the heat-pump water heater.

replace the home-brewed furnace (we needed homeowner's insurance and they wouldn't insure David's furnace), David mounted another water jacket inside the new wood furnace to serve the same water-heating preheat function.

In 2014, David repaired the copper piping within the collectors and mounted the collectors below the deck, facing south, to maximize solar gain and so it could directly thermosiphon to the water heater tank on the first floor. This tank was once a propane water heater, but is now our "pre-heat" tank that holds 40 gallons of hot water, supplying the heat-pump electric water heater in the basement.

A wood-fired furnace, with a water jacket, combines with a heat-pump water heater and a solar preheater (shown in photo above).

In 2013, we installed a Stiebel Eltron 80-gallon heat-pump water heater. It used around 4 kWh per day (compared to the previous gallon of propane per day) before David rebuilt and re-installed the solar water heating system. Now it uses less than 0.5 kWh a day. Next to the furnace in the basement, it takes the preheated water from the preheat tank on the first floor as input water. In the winter, the preheated water enters at about 100°F—the heat pump is very efficient in the winter with warm air input from the heated basement. When the sun is shining, the water is already at 125°F to 130°F from the solar collectors and the water heater rarely comes on at all.

The wood furnace, fired with wood harvested on our property, supplements solar space heating in the winter. In the spring and fall, our enameled 1929 wood cookstove sees frequent breakfast use and warms the house when it's a bit too chilly to wait for passive heating from the sun, but too warm to run the furnace.

Microhydro Details

David—We were living off-grid in the middle of the woods, quiet and peaceful. We had a series of hydro-electric systems to generate some power starting in 1977. That year, I built a Pelton wheel. In 1980, I bought a Harris Hydro wheel with bolted-on buckets. When we contacted Don, the owner, for an upgrade (the bolts tended to loosen), he traded us a new, riveted wheel for the old one at no charge.

The head is about 462 feet, yielding 200 psi static pressure at the house. The flow ranges from 20 gallons per minute in a good winter to less than 10 gpm in spring and fall. Today, we share the water system with two other properties and use our hydro system from November 1 to April 30 under our hydroelectric water right—and, under our domestic and agricultural water rights, as far into the late springtime as we can when there is sufficient flow.

In 2013, we upgraded the hydro turbine to a Pelton wheel with a 48-volt permanent-magnet alternator, custom-tuned from Alternative Power & Machine (APM), in hopes that the system would be more efficient and produce more energy at lower flows. The new alternator, while more efficient, is noisy. At first it was nice, hearing it humming away above the house—but we missed the quiet we had. So I built a 4-by-8-foot shed around the culvert outfall and Pelton wheel assembly.

It turned out that the building was a resonator, and noise from anything connected to it was amplified. I isolated any vibration-makers that could reach the building, including the water inlet and outlet, as well as the turbine and culvert outfall structure. Where the water inlet enters the building, I widened the hole to prevent direct contact of the pipe with the wall, and caulked around it.

We've learned that a little bit of falling water can go a long way. Maybe it seems silly to have a hydro generator that "only" provides 300 watts, but that comes out to 7.2 kWh per day, which serves many household loads.

Microhydro Tech Specs

Overview

Site head: 462 ft.

Resource flow (dry season): 10 gpm

Resource flow (wet season): 20 gpm

Production (dry season): None

Production (wet season): 216 AC kWh per month, avg.

Civil Works

Intake: Fully enclosed redwood spring box, 8 x 8 x 3 ft.

Penstock: 5,000 ft. of 1.5-inch PVC pipe

Powerhouse: 4' x 8' plywood building, insulated, metal-roofed, containing a 24-in. diameter, 3-ft. tall culvert section, set in the concrete floor

Microhydro Turbine

Turbine: Brass Harris Pelton wheel

Runner diameter: 6 in.

Alternator: Permanent-magnet, 48 VDC

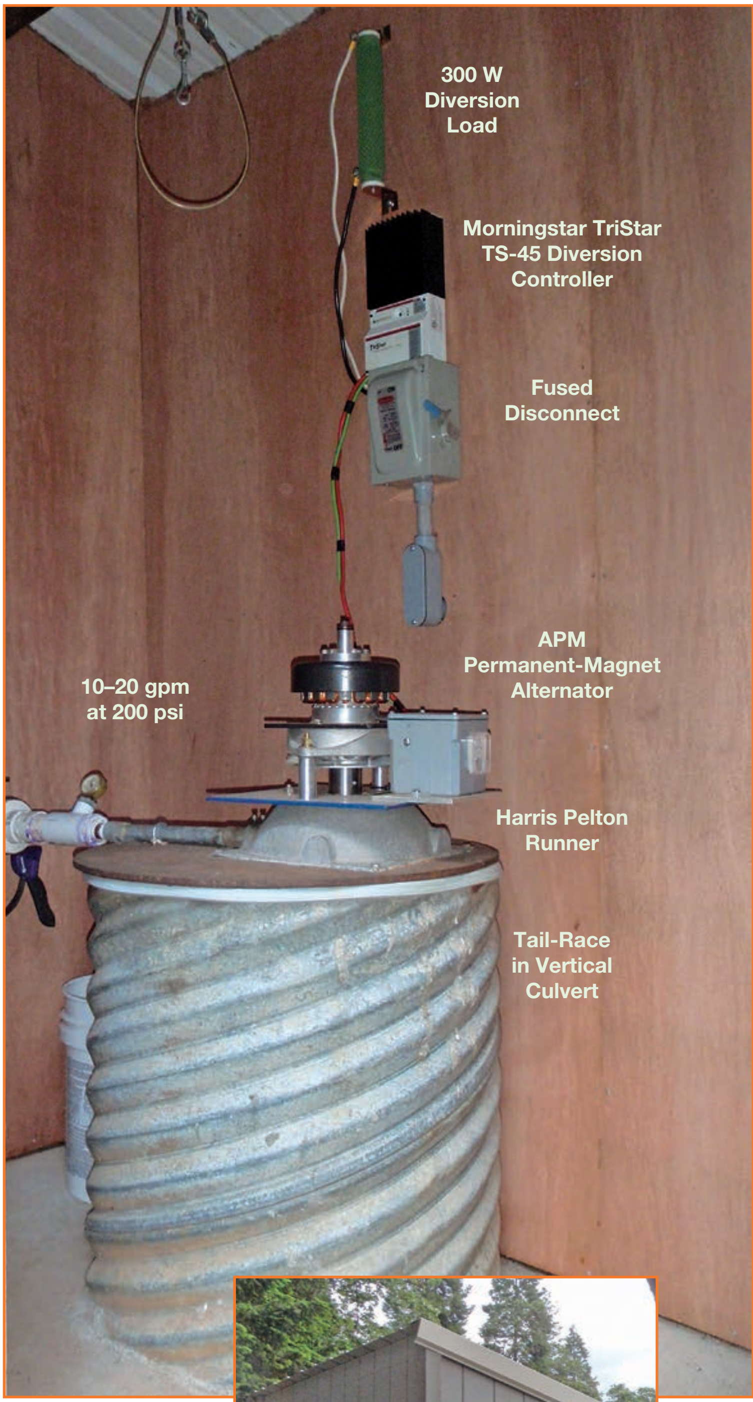
Rated peak power output: 0.3 kW

Microhydro Balance of System

Hydro turbine controller: TriStar TS-45

Diversion load: 300 W resistor

Circuit protection: 30 A fuse



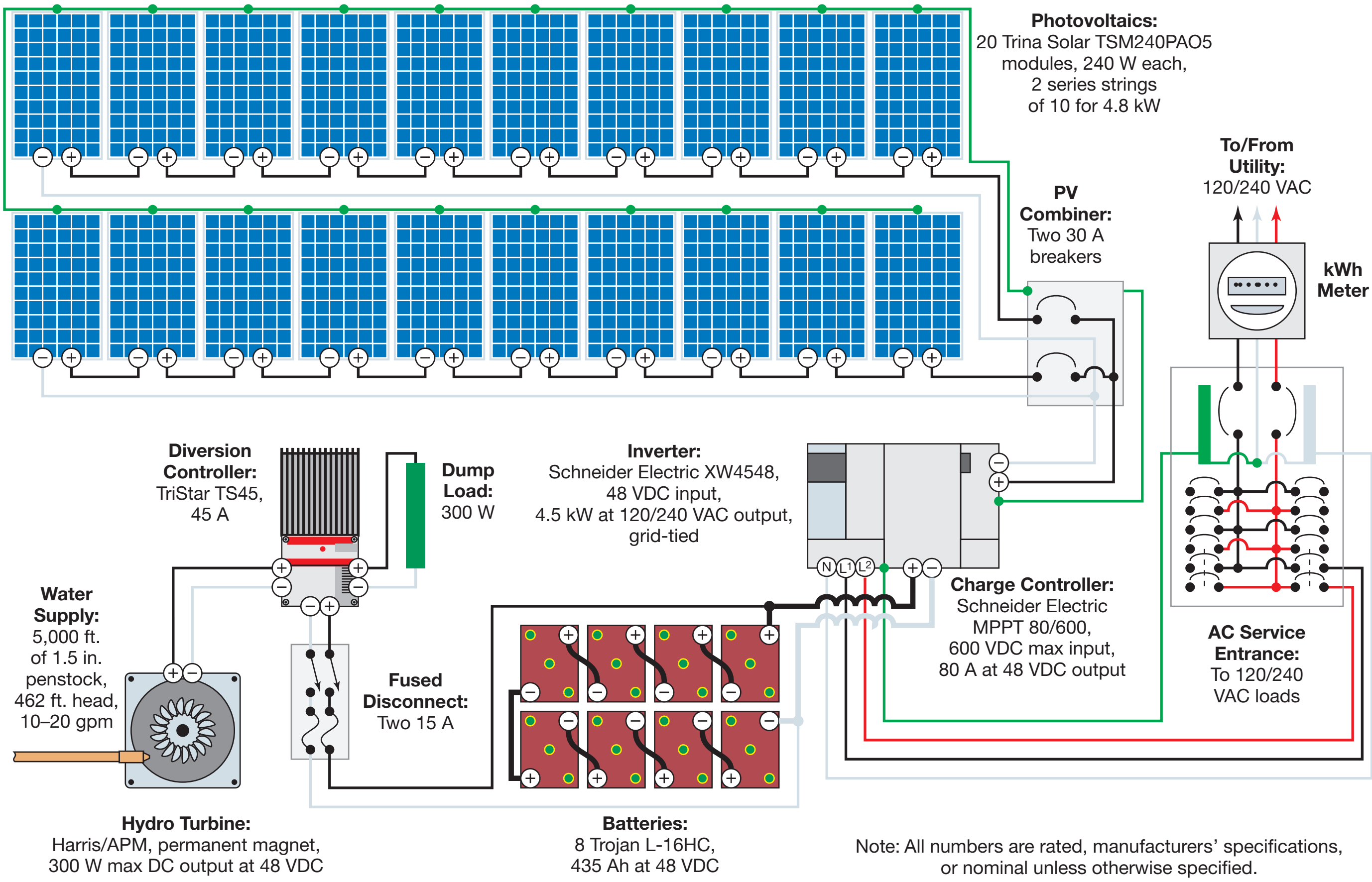
PV System Details

In 1983, we worked with a local business to buy one of its first off-grid solar-electric systems: a Best modified square-wave inverter (3,500 W) and a home-brew controller; four Arco 16-2000 (33-watt) solar-electric modules on a Zomeworks tracker; and six 12-volt deep-cycle batteries. The battery-based system, charged by a microhydro turbine and PV modules, powered a small refrigerator, a small TV, and DC lights. In those days, the state of California gave a 55% tax credit for RE systems, so we had fairly "cheap" electricity.

In 1986, with the birth of our second child (and a desire for a freezer, which drew more electricity than our RE system could supply), we started to work with Pacific Gas & Electric (PG&E) to install utility lines to our place. Three neighbors were also interested. PG&E reported spending $88,000 to install the line that stretches 2 miles from the main line, which feeds the nearby town of Orleans, to the last house above us. However, with the credits available through the Rural Electrification Administration for adding electrical appliances, each property owner only paid $2,400. That said, we Eckerts did all of the engineering, laid out the right-of-

Until modifications were made, the power shed amplified the noise of the microhydro turbine.

Eckert Hybrid PV & Microhydro System



way, bought a timber-sale from the Forest Service for the portion across National Forest, and used the proceeds from that sale to pay for the rest of the right-of-way clearing on all four properties.

Our utility electricity is through a side feed and only supplies three properties—it's hardly a "grid." We and our neighbors expect at least two scheduled day-long outages a year for maintenance and repairs, and at least four unplanned outages that can last from a few hours to several days during the year due to windstorms, fallen trees and branches, heavy snow, or wildfires. So when we considered another solar-electric system, we knew we wanted a hefty battery backup system. We like the idea of being independent of utility power—no matter how handy PG&E net metering is, we know the program could be cancelled some day, so we wanted the option of being off-grid capable.

Right: A Schneider Electric charge controller and inverter are mated to the AC and DC distribution panel for a unified installation.

Left: Eight Trojan L-16HC batteries provide 435 Ah of energy storage capacity at 48 VDC.

Twenty Trina Solar 240 W PV modules provide 4.8 kW of rated solar power.

PV Tech Specs

Overview

System type: Battery-based grid-tied solar-electric

Installer: David Eckert

Date commissioned: April 2013

System location: Orleans, California

Latitude: 41°N

Solar resource: 5.49 average daily peak sun-hours

Production: 513 AC kWh per month, avg.

Photovoltaics

Modules: 20 Trina Solar TSM-240PA05, 240 W STC, 29.2 Vmp, 38.0 Voc, 8.23 A Imp, 8.65 A Isc

Array: Two 10-module series strings, 4,800 W STC total, 292 Vmp, 380 Voc

Array combiner box: MidNite Solar with 15 A breakers

Array disconnect: Internal to Xantrex distribution box; 60 A breaker. GE Type 3 30 A breaker, outside

Array installation: SnapNrack mounts installed on south-facing roof, 14° tilt

Engine Generator

Make/model: Honeywell 7,000 W with Honda GX390 engine

Energy Storage

Batteries: Eight Trojan, L-16HC deep-cycle lead-acid, 435 A at 20-hr. rate, 6 V each

Battery bank: 48 VDC nominal, 435 Ah total

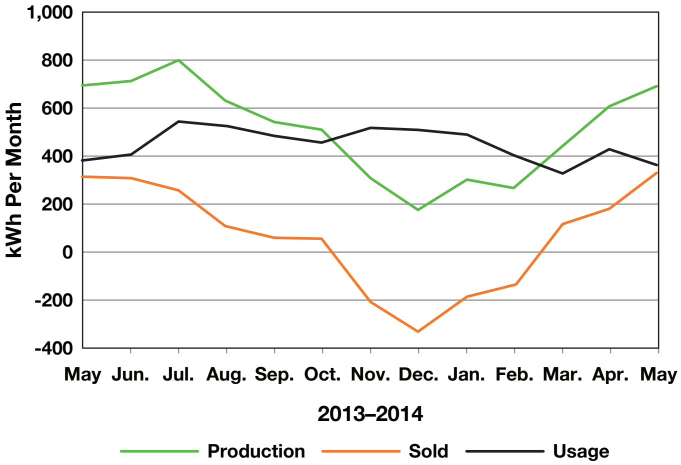
Battery/inverter disconnect: 250 A breaker

Balance of System

Charge controller: Schneider Electric, 80 A, MPPT, 600 VDC max input voltage, 48 VDC output voltage

Inverter: Schneider Electric 4548, 48 VDC nominal input, 120/240 VAC output

PV Production & Home Use



We liked the Zomeworks tracker in our first PV system—it was an elegant solution that depended only on solar energy to function. But solar-electric module prices have dropped so much that it is cheaper per watt to add more PV than to add a tracker to get the same production. Our second array—4.8 kW of grid-tied PV—is mounted on the house's south-facing roof.

In the basement, I installed a Schneider Electric (Xantrex) XW4548, 4,500-watt, 48-volt inverter; an 80-amp, 600-volt Schneider Electric MPPT 80/600 controller; a power distribution panel; and a system control panel. Just outside under the deck, I installed the eight Trojan L-16HC deep-cycle batteries in a custom-built, vented, and waterproof battery box. We "threw the switch" and connected the system to the grid in April 2013.

Eckert PV System Costs

Item	Cost
20 Trina PV modules	$10,392
Xantrex 4548 inverter	4,276
8 Trojan L-16 batteries	3,031
SnapNrack roof rack system	2,869
Sales tax	1,967
Xantrex 80/600 power controller	1,732
Xantrex power distribution panel	1,624
Battery box	406
DC disconnect	330
Xantrex system control panel	325
Cables & wire	271
MidNite Solar combiner box	194
3 Breakers	146
WEEB grounding clips	103
Lightning arrestor	65
Ground rod	49
Total Cost	$27,778
Federal Tax Credit	-$7,743
Net System Cost	$20,035

David and Penny use their surplus RE energy to charge a new set of wheels, a Ford C-Max Energi plug-in hybrid.

Penny—Our first-year results have been interesting. We broke even at the time of the PG&E annual true-up at the end of March—they credited us $31. But the meter showed 600 kWh more sold by the end of May than it did on the same date last year, so to avoid donating power to PG&E, we bought a plug-in hybrid car. Ruby C. Max, our 2014 Ford C-Max Energi, has a 19-mile electric-only range, which gets us to Orleans every day for the mail on a 7 kWh charge, and is fun to drive as a hybrid on longer trips at more than 60 mpg overall. That should take care of the surplus and reduce our carbon footprint, too!

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Clarifying Codes
for Solar Water Heating Systems

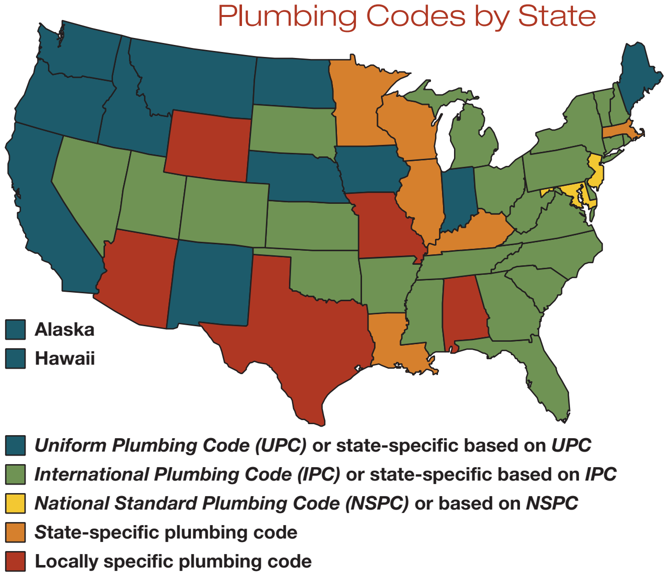
by Vaughan Woodruff

Though still lacking national uniformity, some code requirements for solar water heating (SWH) installations are gaining clarity in 2015.

Unlike PV system requirements, which have significant uniformity due to the use of the *National Electrical Code (NEC)*, SWH requirements vary depending on which code sets are used. Jurisdictions usually adopt one of two primary plumbing and mechanical codes—the *Uniform* code or the *International* code ("I-code"). Lack of uniformity leads to significant differences in SWH system requirements between jurisdictions. To identify the requirements for installing a system in your particular area, you will need to know which code(s) are relevant in your jurisdiction. Chances are that you need to follow either the *Uniform Plumbing Code (UPC)* or the plumbing section of the *International Residential Code (IRC)*. But if you live in New Jersey or Maryland, you need to follow the *National Standard Plumbing Code*.

While 2015 code changes will not resolve this lack of uniformity, they will provide more explicit code requirements for SWH systems installed in states that have adopted the I-codes. This is a result of collaboration between the International Code Council (ICC) and the Solar Rating & Certification Corporation (SRCC), which officially merged in 2014. This relationship has resulted in a significant reworking of the Solar Energy Systems chapter of the *IRC*, which applies to one- and two-family dwellings.

Plumbing Codes by State



Uniform Codes

SWH system requirements in the *Uniform* codes have been more comprehensive than the I-codes due to the *Uniform Solar Energy Code (USEC)*. Published by the International Association of Plumbing and Mechanical Officials (IAPMO) since 1975, the *USEC* provides a stand-alone code for solar energy (including PV) system installation. The 2015 *USEC* is currently in development and has expanded to incorporate hydronic heating, including radiant distribution and ground-source heat pumps, and will be renamed the *Uniform Solar Energy and Hydronics Code (USEHC)*. While the *USEC* has been adopted only in Alaska, New Mexico, and a handful of municipalities in several other states, the document also provides guidance specific to SWH system installation in other jurisdictions that have adopted the *UPC*.

The requirements of Chapter 23 in the 2012 *IRC* were fairly limited and touched mostly on requirements from other portions of the *IRC* that deal with the installation of water heaters, mechanical equipment, and roofing. The major SWH-specific requirements in the 2012 *IRC* ensure freeze protection for systems that will experience temperatures below 32°F, and verify that collectors are listed and labeled.

Confusion in the 2012 *IRC*

While the SWH requirements of the 2012 I-codes are few, those that are included have caused confusion among the code community. For instance, 2012 *IRC* M2301.2.8 stipulates that "valves shall be installed to allow the solar collectors to be isolated from the remainder of the system." If interpreted literally, this could result in isolating the heat source of the system—the solar collectors—from the relief valve, which could lead to excessive pressure and catastrophic failure if the valves were ever closed. 2012 *IRC* M2301.2.3 recognizes this to an extent by requiring that "relief valves shall be installed in sections of the system so that a section cannot be valved off or isolated from a relief device." This vaguely written section contradicts M2301.2.8. It would seem to require two relief valves in the solar loop of a system—one for each portion of the system that can be isolated. A second relief valve would be unnecessary in many SWH systems, where the only pressure hazard is on the collector side of the isolation valves, due to the heat they generate.

continued on page 70

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Another section of the 2012 *IRC* demonstrates a limited understanding of SWH systems. 2012 *IRC* P2902.5.5 stipulates that "the potable water supply to a solar system shall be equipped with a backflow preventer." An exception is given for systems where the solar collectors directly heat potable water. This requirement has caused confusion in some jurisdictions that have interpreted "the potable water supply to a solar system" to mean the potable water supply to the water heater.

This portion of the 2012 *IRC* is an example of taking a requirement for a similar technology—in this case, boilers—and applying it to SWH systems. With boilers, this requirement refers to a direct connection between the potable water and the mechanical piping. This occurs when an autofill valve is installed to provide makeup water in a boiler. Standard SWH systems do not have this type of direct connection between the mechanical piping—the solar loop—and the potable water supply. This misunderstanding has led to inappropriate requirements that put local code officials in a difficult position if they have a limited understanding of SWH systems. In some states, this misunderstanding has led to a restrictive interpretation of the code that increases the complexity and cost of systems without providing a tangible health or safety benefit. This has significantly limited the installation of code- compliant systems in these areas.

Improvements in the 2015 *IRC*

Updates in the 2015 *IRC*, particularly in Chapter 23, provide more specific guidance. There are also key updates in two of the plumbing chapters, 28 and 29.

Inclusion of SRCC Standard 300. A key part of the collaboration between SRCC and ICC in this code cycle is the codification of many portions of SRCC Standard 300 (SRCC 300), a standard used to verify certification for residential SWH systems. Requirements in the 2015 *IRC* that refer directly to SRCC 300 include: protecting exposed sensor wire from ultraviolet (UV) light (M2301.2.2.2); pressure relief-valve installation (M2301.2.3); storage tank sensor installation (M2301.2.7); system labeling (M2301.2.10); and heat exchanger and heat-transfer fluid characteristics (M2301.4). These references require knowledge of SRCC 300.

Collector listing and labeling. The 2015 *IRC* M2301.3.1 states that "[s]olar thermal collectors and panels shall be listed and labeled in accordance with SRCC 100 or SRCC 600." SRCC 100 refers to SRCC Standard 100, which is test methodology for flat-plate and evacuated-tube collectors. SRCC Standard 600 is used for concentrating collectors. This means that collectors certified by SRCC and IAPMO are code-compliant, since both organizations use Standard 100 to certify collectors. This may create a challenge in Florida, where collectors are currently certified by the Florida Solar Energy Center (FSEC) under its own standard.

More Info

International Residential Code **• iccsafe.org**

SRCC Standard 300 • solar-rating.org

Uniform **codes • codes.iapmo.org**

The Codes

International Residential Code (IRC)—applies to one- and two-family dwellings and includes requirements related to building construction, plumbing, heating and cooling, and electrical work.

Uniform Plumbing Code (UPC)—applies to residential and commercial plumbing systems.

Uniform Solar Energy and Hydronics Code (USEHC)—applies to residential and commercial solar heating and solar electric systems, as well as radiant distribution and heat pumps used for heating and cooling.

Uniform Solar Energy Code (USEC)—applies to residential and commercial solar heating and solar electric systems; becomes the *USEHC* in late 2015.

Backflow prevention. Chapter 29 of the 2015 *IRC* was updated to address some of the vague requirements related to backflow prevention in the 2012 *IRC*. For example, 2015 *IRC* P2902.5.5.1 explicitly states "water supplies of any type should not be connected to the solar heating loop of an indirect solar thermal hot water heating system." This clarifies the confusion in the 2012 *IRC* P2902.5.5, which inferred that backflow preventers might be required in indirect SWH systems like antifreeze and drainback systems. The update clarifies that a backflow preventer is needed only with a SWH system that directly heats water for nonpotable uses. The purpose of this requirement is to ensure that this type of system—which is extremely rare in residential applications—could never push the heated liquid in the solar loop back into the potable water supply.

Water-temperature control. One of the oversights in both the *UPC* and the *IPC* is the failure to recognize the high water heater temperatures unique to intermittent heating sources like solar. Since the sun's energy cannot be summoned whenever needed, it is common practice to store as much heat as possible when solar energy is available. This may result in tank temperatures approaching 180°F—a scald hazard in plumbing fixtures. Until the 2015 updates, the only stipulation related to mixing valves for water heaters was 2012 *IRC* 2802.2, which required thermostatic mixing valves be installed "[w]here a combination water heater-space heating system requires water for space heating at temperatures exceeding 140°F." A provision in the 2012 *USEC* is almost identical. The 2015 update to the *IRC* recognizes that SWH systems are unique and should always have a thermostatic mixing valve to ensure delivered water temperatures do not exceed 140°F. A similar requirement has been approved for the 2015 *USECH*—see "*Uniform* Codes" sidebar.

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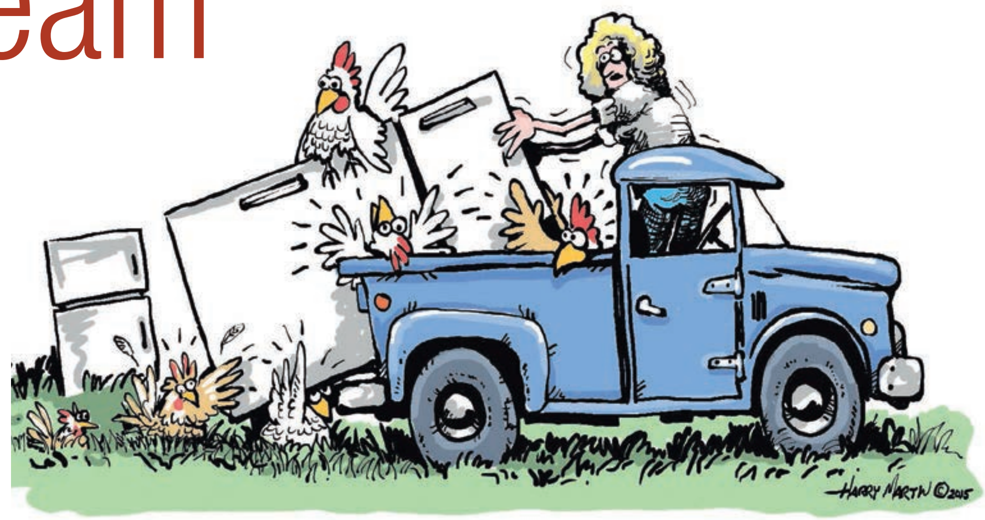
Root for the Home Team

by Kathleen Jarschke-Schultze



Having lived and gardened off-grid for the last 30 years, I am fascinated by food preservation methods. My favorites are the ones that use the fewest resources to save the harvest. Some methods—like reusable canning jar lids—are possible because of current technologies. And some preservation methods are as old as the hills.

Root Cause

My husband Bob-O and I farm three large garden areas beside our creek. We are well-acquainted with the concept of seasonal eating. Right now, we are eagerly awaiting the first spears of asparagus to shoot up through the soil. Meanwhile, the snow peas and sugar snap peas I germinated by soaking them for two days are now planted in rows on both sides of a trellis. In summer and fall, we enjoy tomatoes, summer squash, okra, melons, corn, and other warm-weather crops. During that time, I'm busy canning, fermenting, freezing, and drying food. This is also when root cellaring makes my life easier.

Family Roots

During my childhood, one of the older houses my family lived in had a kitchen with a root-cellar cupboard. In the corner of the kitchen, away from the stove, there was a tall cupboard with open wooden slats instead of solid shelves. This is where we kept the potatoes, onions, and winter squash. A simple screened vent brought air from underneath the house through the cupboard slats, exiting under the eaves.

I don't have such a wonderful cupboard in my house, but through trial and error, I have found the best places to keep certain harvested crops into the winter (and, in some cases, even spring). My apples go into buckets in our attached mudroom. Red chile ristas hang by my desk. We are lucky to have a half basement with three sides below grade. The fourth side contains double doors that open into the carport below our deck. Because it is the northeast side of our house and shaded by the deck, it is very cool all year 'round. I braid garlic and onions, or put them in a net bag and hang them from the basement walls and supports. Large tubs in the basement hold the different varieties of winter squash. Out in our "Keep"—a buried 20-foot-long steel shipping container—I have a small wooden dresser. The top three drawers hold my seed collection, collected from year to year. The two deep bottom drawers are lined with newspaper and hold our potatoes. (Read about the Keep in "Containing the Zombie Apocalypse," *HP140*.)

I tried to keep my carrots in the Keep. I layered them in wet sand inside small wooden crates. I used layers of flat cardboard to cover the crates to slow moisture evaporation, but I was never pleased with the result. The carrots dried out too quickly and did not last long. Cabbage has also been a storage problem for me. Stored as sauerkraut, it's no problem, but whole heads have always spoiled no matter where I've stored them.

Take Root

I know the exact place where I want to build a concrete-brick-walled, dirt-floored root cellar. My problem is that at least two other rather large projects must be completed before I can start my dream cellar. I can't wait that long, so I've improvised in the meantime.

I stopped at a local business that refurbishes and sells appliances. I had seen their lot filled with old refrigerators and freezers. I told the guy I was looking for a large upright dead freezer with a good door seal. He said he couldn't remember ever being asked for that before. We walked around the yard, sidling around and between a large array of discarded monolithic hulks. He showed me three different freezers, all destined for the scrapper. I chose the one he recommended once I had eagerly told him my plan. I paid him $20 and we loaded it into the back of Bob-O's truck.

Up Root

When we got home, we backed into the carport under the deck and unloaded the freezer. We positioned it to sit on its back just outside the basement door. The freezer door now opens upward, like a chest freezer.

My dead freezer measures 65 inches long by 32 inches across and is 25 inches deep. It is very old—and heavy. The inside walls are enameled metal, not plastic.

First, I thoroughly washed all the surfaces. I scrubbed the metal wire shelves and slid them back into place as dividers. I stuck an inexpensive dual thermometer/humidity gauge to the inside the door so I could keep tabs on how well it was keeping things cool.

This is a really cheap way to store some root crops until I have a real root cellar. I figured if it worked outside the back door, I'd leave it there. If it got too cold and everything froze, I would have to bury the freezer and put vent pipes in next summer.

Putting Down Roots

The preparation needed for storing most root crops is just digging them up. Part of the attraction of root cellaring was that I only need to knock off most of the dirt from the root crop and put it in the cellar. Cleaning takes place before you eat the root—not when you store it.

Only vegetables in good condition should be stored. Every bruise and every cut is a gateway for spoilage. There is vegetable attrition, and those roots that succumb to rot should be removed promptly to prevent spreading spoilage. Any root cellar needs airflow. My "cellar" could probably use some vents, but so far my normal opening and closing of the door has been enough.

The first thing I harvested and stored were carrots. I packed them in damp sawdust in wooden boxes. I had some really good-looking cabbages I placed between two wire dividers, along with some Daikon radish. I tried storing beets in there, but they quickly rebelled and were removed. To my delight, the carrots and some of the cabbages are still good and find their way into our meals.

Rootstock

In February, it was our turn to host the informal neighborhood dinner club. Seasonally appropriate, the theme was "The Root Cellar." I chose the food each person would bring, but left specific recipe choices up to them.

Appetizers were pickled beets and root-crop crudités. The main dish was spaghetti squash with pasta sauce. Side dishes were scalloped potatoes and a carrot/cabbage salad. Dessert showcased a French squash tart made with butternut squashes. With wine and music, it was a memorable dinner.

I enjoy using the food we produce each year. We like to recite each part of our meal that was grown by us. One of my favorite dishes is made from our winter storage vegetables. I was thinking, what would be left in a farmer's root cellar just before spring? Potatoes and cabbages, that's a sure bet. Colcannon has the humblest of beginnings, but is a most delicious dish. To make colcannon, mash some hot cooked potatoes (I leave the skins on). Add medium-sized cabbage shreds to the still-hot potato mix and cover for a couple of minutes. The potatoes steam the cabbage to a tender bright green.

Preserving our harvest and eating the good food we grow throughout the year is, in large part, why we live where and how we do. Root cellaring resources in the form of books, e-books, blogs, videos, and threads abound. Do some homework and don't be afraid to experiment. If you want to try one of the oldest food preservations methods on (or in) earth, well, I'm rooting for you.

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Earth-Coupling

In certain climates, earth-coupling a home—building into the ground to tap into the earth's thermal mass and the soil's fairly constant temperature—can make sense. Think of Pa and Ma Wilder's underground home on the prairie, which helped shelter them from the wicked winter weather and sweltering summer sun.

At the surface, soil temperature is influenced by solar radiation, rainfall, air temperature, ground cover, and soil type. Compared to air, soil has a much greater heat capacity—the ability to hold heat. Surface soil layers and vegetation also provide some insulation, slowing heat transfer. That's why, deep down, seasonal soil temperature changes lag appreciably behind seasonal air temperature changes. At a certain depth, the ground temperature is always higher than that of the outside temperature in winter and is lower in the summer. According to the *ASHRAE Handbook of HVAC Applications*, the soil temperature beyond a depth of about 3 feet is usually unreactive to the daily cycle of air temperature and insolation. About 30 feet below the surface, the soil temperature stays fairly constant all year.

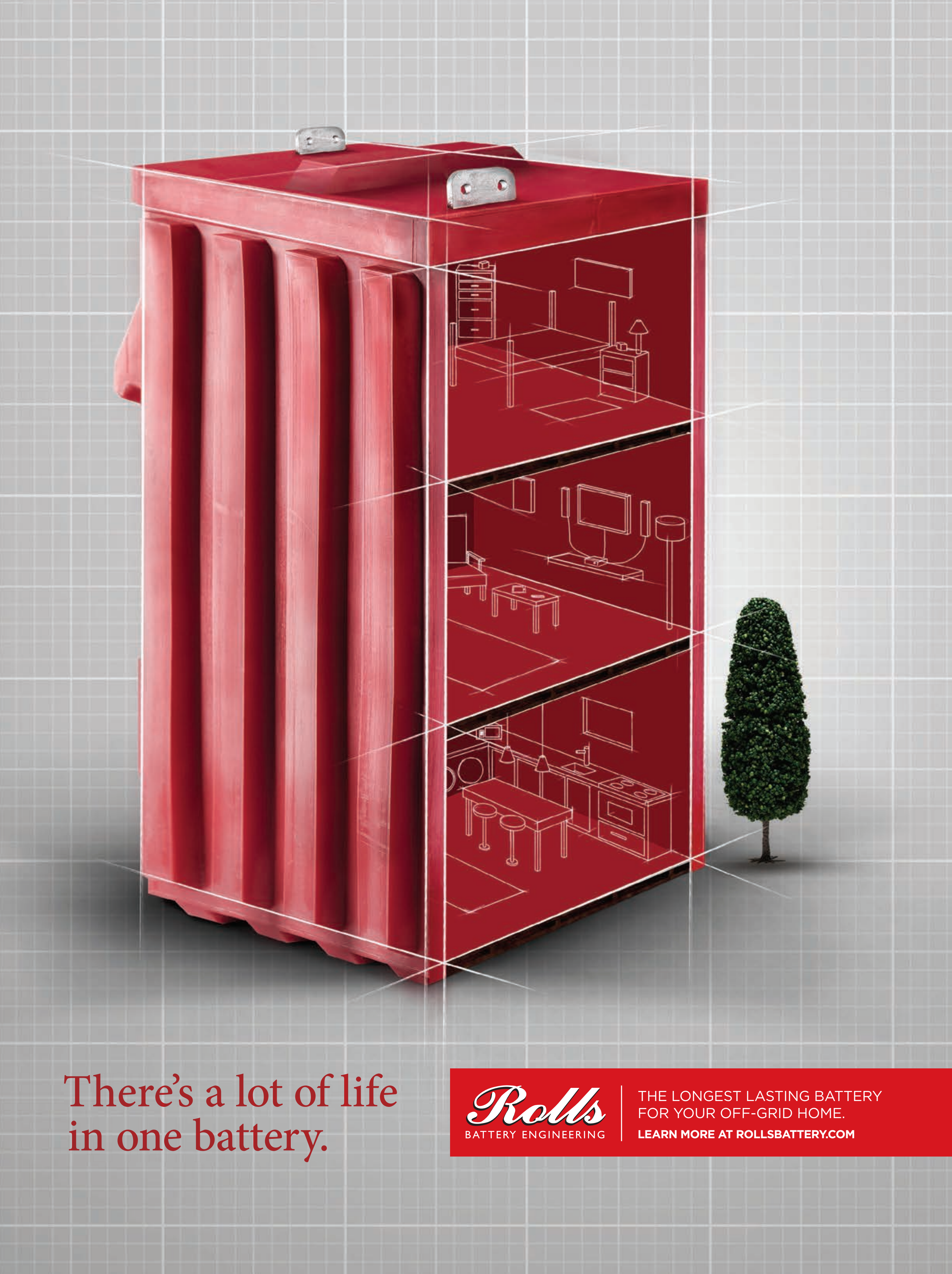
There are ways to put the earth's thermal mass to good use in your home without digging too deeply. In places where cooling degree-days (the number of days that supplemental cooling is needed) trump heating degree-days—like Phoenix, Arizona (4,355 CDDs vs. 1,350 HDDs), direct-earth coupling could be advantageous. For example, in this region, a slab-on-grade home could potentially take advantage of the earth's "cooling" capability, depending on the soil temperature. Say you were willing to have a summertime thermostat setting of 76°F or above, and typical soil temperatures near the surface hover around 72°F—Phoenix's average annual air temperature. Under these conditions, the heat flow would be from the warmer house, through the slab, and into the earth below. In the winter, an interior thermostat setting that's lower than that soil temperature would result in heat being transferred *into* the house. In this design, the slab is left uninsulated, but the perimeter foundation is insulated. Shallower soils still have seasonal temperature fluctuations, and insulating at a depth that's well beyond the frost line is necessary to achieve benefits from earth-coupling.

Earth-berming—or indirect earth-coupling—is another way to tap into the earth's thermal mass. Typically, earth-berming is used to shelter a home, usually on windward sides, tempering the effects of the climate. However, insulation (and moisture-proofing) is installed between the home's walls and the soil, and the slab is (usually) also insulated. According to the Department of Energy, studies show that earth-sheltered homes are most economical in areas that have "temperature extremes and low humidity," such as the Rocky Mountains and northern Midwest.

—Claire Anderson

Courtesy NREL/David Aitken

This earth-bermed home, located at 7,500 feet in the Rocky Mountains near Aspen, Colorado, obtains 90% of its winter heating requirements from the sun.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